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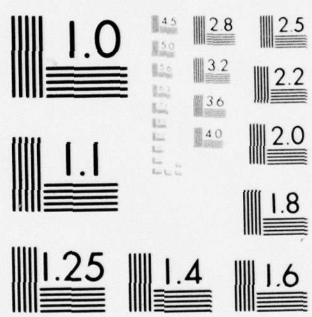

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Bethesda, Md. 20084

MERCHANT SHIPPING AND TRANSFER CRAFT REQUIREMENTS IN SUPPORT OF AMPHIBIOUS OPERATIONS

by

Michael Gray

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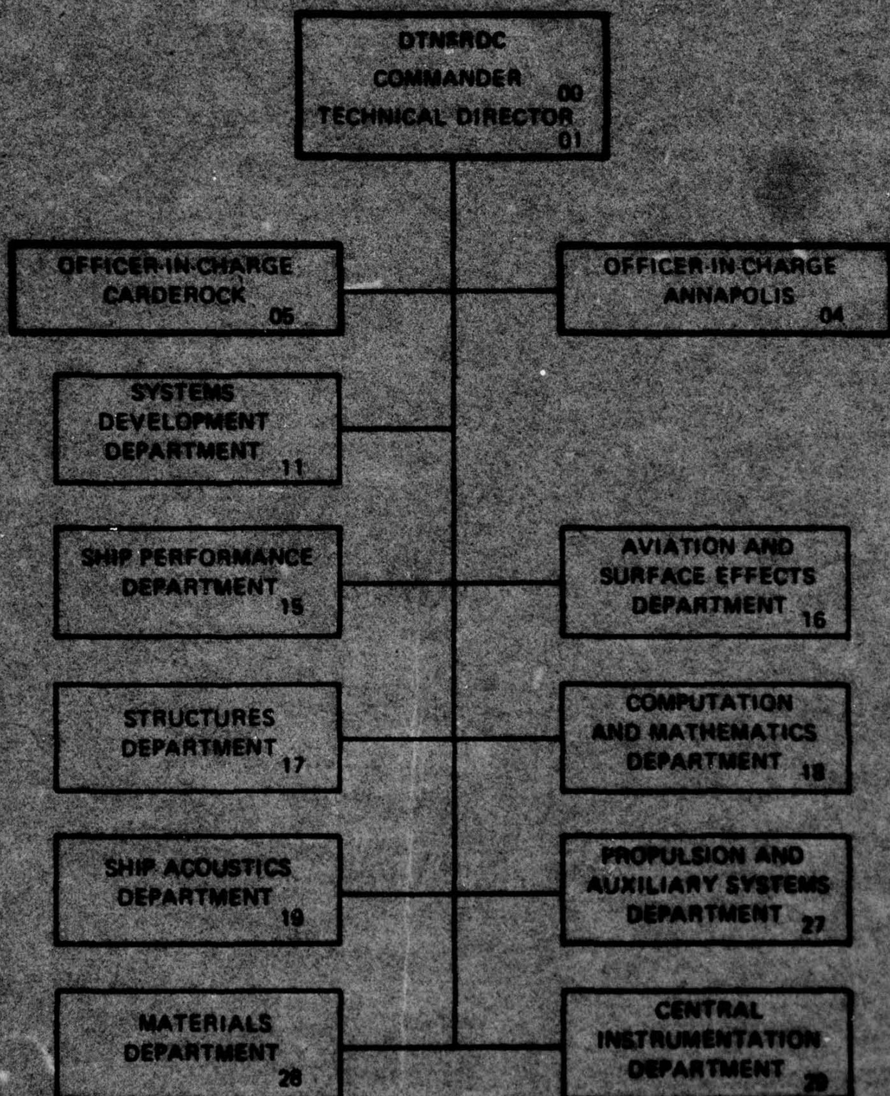

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER: DTNSRDC ~~Report~~-77-0039 (14)	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle): MERCHANT SHIPPING AND TRANSFER CRAFT REQUIREMENTS IN SUPPORT OF AMPHIBIOUS OPERATIONS. (6)		5. TYPE OF REPORT & PERIOD COVERED: (9) Final rept.,
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): (10) Michael/Gray		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: (1) David W. Taylor Naval Ship Research and Development Center Bethesda, Maryland 20084		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: P.E. 62760N Task Area TF 53 531 005 Work Unit 1-1867-010
11. CONTROLLING OFFICE NAME AND ADDRESS: Naval Supply Systems Command (043) Research and Development Division Washington, D.C. 20390		12. REPORT DATE: (11) Apr 1977
		13. NUMBER OF PAGES: 116 (12) 118p.
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office): Plans and Studies Division Development Center MCDEC Quantico, Va. 22134 (16) F53531		15. SECURITY CLASS. (of this report): UNCLASSIFIED
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report) (17) TF53531005

APPROVED FOR PUBLIC RELEASE: DISTRIBUTION UNLIMITED

DDC APR 25 1977 C

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Landing Craft	Assault Follow-on Echelon	Offshore Discharge
Causeway Ferry	Container Ship	Simulation
Scenario	Breakbulk Ship	Shortfall
Marine Amphibious Force	Roll-on/Roll-off Ship	Amphibious Operations
Logistics	LASH Ship	System Effectiveness

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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Two computer models were used to simulate these operations. Results indicate that, although container ships are generally highly productive, the long lead times required before they are available and their complex unloading requirements decrease their productivity in over-the-beach operations. Breakbulk ships are less productive but are largely self-sustaining, except that they require transfer craft for unloading. RoRo ships and barge carriers are highly productive and generally can be made self-sufficient but are available in limited numbers.

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ABSTRACT

The use of merchant ships to supplement Navy ships in filling the lift requirements in transporting the assault follow-on echelon of a Marine Amphibious Force during amphibious operations has been analyzed. The analysis was based on detailed characteristics and loading/unloading operations of the merchant ships in both in-port and over-the-beach situations. It included consideration, in over-the-beach operations, of ship unloading platforms, transfer craft, and cargo handling devices ashore.

Two computer models were used to simulate these operations. Results indicate that, although container ships are generally highly productive, the long lead times required before they are available and their complex unloading requirements decrease their productivity in over-the-beach operations. Breakbulk ships are less productive but are largely self-sustaining, except that they require transfer craft for unloading. RoRo ships and barge carriers are highly productive and generally can be made self-sufficient but are available in limited numbers.

SECTION 1
INTRODUCTION

The Navy has retired most of its old amphibious ships and personnel carriers. Ships now in use constitute a streamlined and modern amphibious force of 65 ships with an average speed of 20 knots. However, the size of this fleet is insufficient to provide amphibious lift capability for Marine Amphibious Force (MAF)* operations. It has thus become necessary to obtain additional lift capability from other sources.

Airlift is one possibility. Although faster than sealift, it has shortcomings. The large size of the MAF makes it infeasible to transport it by air, although smaller forces, possibly a light Marine Amphibious Brigade (MAB), might be handled this way. In addition, the airfield required is vulnerable to attack.

The U.S. merchant fleet and the merchant ships of the Military Sealift Command (MSC) could also provide additional lift capability. Merchant ships can be obtained under contract by the Government and those with large cargo-carrying capacity are well-suited for transporting the heavy follow-on echelon of a MAF, i.e., the Marine Air Wing and the Force Troops. The lighter assault echelon can be carried by amphibious ships as is traditionally done.

The major problem in utilizing merchant ships relates to the offshore discharge of cargo. Since most merchant ships were not designed to be unloaded offshore, additional and/or new procedures and equipment will be required. Assessing the usefulness of merchant ships in a MAF-level operation requires information on the needed number and types of such ships, their loading and unloading characteristics, and their availability.

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* See Appendix C for a list of abbreviations and acronyms used in this report

Knowledge of port characteristics is also needed, as port operations affect merchant ship performance.

Instead of delivering cargo to a port, merchant ships can transport their cargo to a position offshore. There the ships can be unloaded and the cargo transported ashore. The number and types of ships, transfer craft, unloading platforms, and cargo handling equipment required to deliver cargo to the beach have been determined for a stipulated set of conditions and no losses due to enemy action.

Cargo is moved from CONUS to an amphibious objective area (AOA) using a system composed of ships, transfer craft, and loading and unloading facilities. To analyze such a system the ship loading, movement, unloading, and delivery phases must be considered interactively. Such representative amphibious operations were formulated into a scenario where the assault follow-on cargo is loaded at CONUS on merchant ships and shipped to an undeveloped beach in Western Europe. The ships are unloaded offshore and cargo is delivered to the beach. The scenario describes an amphibious landing utilizing one MAF and subsequent reinforcements consisting of a 2nd MAF. This report examines the capability of merchant shipping to provide supplemental lift in support of amphibious operations.

A documentation of the computer simulation model used in this report is presently in preparation.

SECTION 2

BACKGROUND

The study of merchant ship applications has been ongoing for 2 years. Initial results were reported by Friedenberg,[1] who examined merchant ships and transfer craft required to deliver a payload over-the-beach to an unimproved beach area. A computer model REACT (see Section 8), simulating only port-to-port operations, was adapted for over-the-beach operations by addition of a small program. Subsequently, a new model called TRADES (see Section 8) was developed to directly simulate port-to-port and port-to-unimproved beach area operations. The TRADES model used in this analysis provided a more flexible and accurate tool for determining ship and craft requirements.

1. Friedenberg, P., "Follow-on and Resupply Shipping Assets for a Representative Marine Corps Situation," DTNSRDC Report 76-0081, January 1976.

SECTION 3
USE OF MERCHANT SHIPPING IN AMPHIBIOUS OPERATIONS

3.1 AMPHIBIOUS WARFARE SHIPS VERSUS MERCHANT SHIPS

Amphibious warfare shipping is designed to transport, land, and support Marines and equipment. Amphibious ships can be unloaded at the Amphibious Objective Area (AOA) by Naval personnel, without the aid of external equipment. Furthermore, rapid offloading of personnel and equipment is possible because these ships carry their own helos, landing craft, and amphibious tractors (amtracs) for offshore unloading; port facilities are therefore not needed. Finally, these ships possess standard military systems such as a combat information center (CIC) and other complex electronic systems, structural compartmentalization, and firepower.

Merchant ships, on the other hand, are designed for use in non-military situtations. Their purpose is to provide fast turn-around time by optimizing cargo carrying capacity and port unloading time. Many ships require exterior equipment for unloading and loading at port facilities, and even more specialized equipment for offshore unloading.

The various phases of amphibious operations were examined to determine merchant ship applications.

3.2 EMBARKATION PHASE

"The embarkation phase is the period during which forces, with their equipment and supplies, are embarked in the assigned shipping".[2]

2. Doctrine For Amphibious Operation ATP-8, COMTAC Publication, Nov 1968

3.2.1 Types of Loading

Two types of ship loading are used during the embarkation phase of amphibious operations; the type used will depend on tactical considerations, ships available, and forces to be moved. Administrative loading "gives primary consideration to achieving the maximum utilization of troops and cargo space without regard for tactical considerations. Equipment and supplies must be unloaded and sorted before they can be used. Administrative loading is employed only for non-tactical movement".[2] The volume capacity of merchant ships is compatible with embarking administrative loads.

Combat loading "gives primary consideration to the facility with which troops, equipment, and supplies can be unloaded, ready for combat on landing, rather than to the economical use of ships' space".[2]

3.2.2 Troop Embarkation

Amphibious ships have specific berthing space for troops; merchant ships have limited or no additional berthing facilites. This is a serious deficiency since unit integrity is frequently required, i.e., the unit must be transported with its personnel and equipment. Berthing space on merchant ships could be obtained by converting unused cargo space, or by deck loading of shelters, i.e., container-size modules on deck could provide living spaces.

3.3 MOVEMENT PHASE

"The movement phase is the period during which the components of the amphibious task force move from the points of embarkation to the objective area".[2] The important consideration in assessing the potential of merchant ships in the movement phase is the speed of the ship. Most merchant ships have speeds of at least 20 knots, which is equivalent to the speed of present day amphibious ships. Thus speed is not a factor in evaluating the use of merchant ships in the movement phase.

3.4 ASSAULT PHASE

"The assault phase is the period between the arrival of the major assault forces of the amphibious task force in the objective area and the accomplishment of the amphibious task force mission".[1] In terms of force movement, the assault phase can be considered in two segments: (1) the assault echelon, "that echelon of the assault troops, vehicles, aircraft, equipment, and supplies required to initiate the assault landing;" and (2) the assault follow-on echelon, "that echelon of the assault troops, vehicles, aircraft, equipment, and supplies which, though not needed to initiate the assault, is required to support and sustain the assault".[2]. Merchant ship use in each echelon will be discussed separately.

3.4.1 Assault Echelon (AE)

The assault echelon is primarily a tactical force and must respond instantaneously to the operational plan. The troops and equipment of the AE must be unloaded rapidly and unit integrity must be maintained. This operation is sustained by amphibious support ships such as LPD's, LSD's, LST's, and LKA's. LPH's add helicopter capability for vertical delivery of troops. These capabilities are not available with merchant ships. Rapid offloading of non-self-sustaining container ships is possible only at piers, not at offshore discharge facilities. Barge carriers and roll-on/roll-off (Ro/Ro) ships can discharge their cargo rapidly offshore but unit integrity would be difficult to maintain because transportation of personnel would be nearly impossible. Furthermore, barge carriers and Ro/Ro's are difficult to obtain because there are relatively few of them and their high productivity places them in demand. Breakbulk ships can be unloaded offshore but the number of active breakbulk ships is decreasing rapidly.

3.4.2 Assault Follow-On Echelon (AFOE)

Because the units in the AFOE are not required in the initial assault and because the offloading times of these units are therefore not as

critical as those of the units in the AE, the use of merchant ships in the movement of the AFOE is more feasible. The use of merchant ships in the assault follow-on phase is practical, especially if such ships can be loaded administratively, insuring their maximum utilization. When unit integrity is desirable, many ships can be altered to provide troop carrying capability.

The difficulty in the use of merchant ships for the AFOE occurs in the unloading of cargo in the AOA for the delivery ashore. Since most merchant ships are designed to be unloaded in port and not offshore (except for barge carriers), additional procedures and equipment will be necessary, as discussed in section 9.

3.5 SUPPORT PHASE

The support phase involving merchant ships is that period during which resupply for the forces ashore is delivered. The size and frequency of deliveries are functions of the size of the force ashore and its length of stay ashore. Merchant ships are suitable for resupply, since administrative loading is appropriate and rapid discharge of cargo at the AOA is generally not required.

SECTION 4
SYSTEM EFFECTIVENESS

Measures of effectiveness are defined to assess the performance of the various ship mixes used to transport the cargo, of the transfer craft needed to deliver the cargo, and of the unloading equipment.

4.1 DEFINITIONS

- Mission - The actions to be taken by the ships and transfer craft to deliver the cargo. The mission duration refers to the time during which the various actions occur. For example, the mission of the merchant ship is to embark and transport the cargo to the amphibious objective area (AOA). The mission of the transfer craft is to deliver the cargo ashore.

- Scenario - The dynamic outline of a synthetic situation in which military operations are conducted. The tactics and operations of the scenario used are not considered explicity. The scenario specifications considered are size of force, embarkation and delivery ports, supply requirements, and response time.

- Supply Classes - The Marine Corps categorizes all material into 10 supply classes as defined in Table 1. The material required by the forces specified in the scenario is constituted of various amounts of these supply classes. Except for personnel (not considered at this time), the entire force can be expressed by the 10 supply classes.

TABLE 1 – SUPPLY CATEGORIES OF MATERIAL

	CLASS	SUBCLASS*
I	SUBSISTENCE	A - Air(inflight rations) C - COMBAT RATIONS** R - REFRIGERATED SUBSISTENCE S - NONREFRIGERATED SUBSISTENCE (LESS C)
II	CLOTHING, INDIVIDUAL EQUIPMENT, TENTAGE, ORGANIZATIONAL TOOL SETS & TOOL KITS, HAND TOOLS, ADMINISTRATIVE & HOUSEKEEPING SUPPLIES & EQUIPMENT	B - GROUND SUPPORT MATERIAL *** E - GENERAL SUPPLIES F - CLOTHING & TEXTILES M - WEAPONS T - INDUSTRIAL SUPPLIES°
III	POL PETROLEUM FUELS, LUBRICANTS, HYDRAULIC & INSULATING OILS, LIQUID & COMPRESSED GASES, BULK CHEMICAL PRODUCTS, COOLANTS, DE-ICING & ANTIFREEZE COMPOUNDS, PRESERVATIVES, TOGETHER WITH COMPONENTS AND ADDITIVES OF SUCH PRODUCTS, AND COAL	A - AIR W - GROUND (SURFACE)
IV	CONSTRUCTION CONSTRUCTION MATERIAL TO INCLUDE INSTALLED EQUIPMENT & ALL FORTIFICATION/BARRIER MATERIAL	
V	AMMUNITION ALL TYPES -- (INCLUDING CHEMICAL, BIOLOGICAL, RADIOLOGICAL, AND SPECIAL WEAPONS) BOMBS, EXPLOSIVES, MINES, FUZES, DETONATORS, PYROTECHNICS, MISSILES, ROCKETS, PROPELLANTS AND OTHER ASSOCIATED ITEMS	A - AIR W - GROUND
VI	PERSONAL DEMAND ITEMS (NONMILITARY SALES ITEMS)	
VII	MAJOR END ITEMS A FINAL COMBINATION OF END PRODUCTS WHICH IS READY FOR ITS INTENDED USE E.G., LAUNCHERS, TANKS, MOBILE MACHINE SHOP, VEHICLES	A - AIR B - GROUND SUPPORT MATERIAL*** D - ADMINISTRATIVE VEHICLES°° G - ELECTRONICS K - TACTICAL VEHICLES L - MISSILES M - WEAPONS N - SPECIAL WEAPONS
VIII	MEDICAL MATERIAL (INCLUDING MEDICAL PECULIAR REPAIR PARTS)	
IX	REPAIR PARTS ALL REPAIR PARTS (LESS CLASS VIII) AND COMPONENTS TO INCLUDE; KITS, ASSEMBLIES & SUBASSEMBLIES, REPARABLE & NONREPARABLE, REQUIRED FOR MAINTENANCE SUPPORT OF ALL EQUIPMENT	A - AIR B - GROUND SUPPORT MATERIAL*** D - ADMINISTRATIVE VEHICLES°° G - ELECTRONICS K - TACTICAL VEHICLES L - MISSILES M - WEAPONS N - SPECIAL WEAPONS T - INDUSTRIAL SUPPLIES
X	NONMILITARY PROGRAMS MATERIAL SUPPORT PROGRAMS E.G., AGRICULTURAL & ECONOMIC DEVELOPMENT, NOT INCLUDED IN CLASS I-IX	

* The subclassification material designators (A through T) may be used in combination. CMC forsees no requirement for this at this time.

** Includes gratuitious health and welfare items.

*** Includes power generators and construction, barrier, bridging, fire fighting, petroleum, and mapping equipment.

° Includes bearings, block and tackle, cable, chain, wire rope, screws, bolts, studs, steel rods, plates and bars.

°° Commercial vehicles utilized in administrative motor pools.

Source: Navy MCS, Quantico, Va.

4.2 AMPHIBIOUS OPERATIONS SCENARIO

4.2.1 Scenario Description

Two MAF's are to be transported to a location in Western Europe. The assault echelon (AE) of the first MAF (the assault MAF) is assumed transported by amphibious shipping and its shipping requirements are not considered. All other forces and supplies are transported by merchant shipping. The assault follow-on echelon (AFOE) of the first MAF consists of Force Troops (FT) and two Marine Air Wings (MAW). The AFOE is to be loaded at CONUS and delivered between D+5 (5 days after D-Day) and D+15. The second or Admin MAF serves as a reinforcement and is administratively loaded on merchant ships. This MAF consists of an AE and Force Troops (less the MAW already delivered) and is required by D+37. Resupply begins at D+15 for the first MAF and at D+52 for the second MAF and is scheduled so as to sustain a build-up of supplies ashore of at least 45 days supply.

4.2.2 Scenario Requirements

The force and resupply requirements were developed by SRI,[3] who combined a number of supply classes and relabeled them. Table 2 indicates the nomenclature used. The total force requirements consist of the basic allowance, supply, and follow-on resupply.

4.2.2.1 Basic Allowance and Initial Supply. The basic allowance and initial supply are carried with the troops onboard the ships as part of the AFOE. The basic allowance consists of the equipment and material carried by the troops and is listed in Table 3 for the Force Troops and MAW. Days of Supply (DOS) are specified in Table 3 under the "No. of days" column for the AE and AFOE. The total initial supply in measurement tons (MT) for each class for the AE and AFOE is determined using the daily resupply rates. The AFOE carries the basic allowance for the FT and MAW's and initial supply for the entire MAF. The total lift requirement of the AFOE is 373,389 MT.

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3. Embarkation Lift Summary System (ELSS) Computer Listing, Stanford Research Institute, March 1971

TABLE 2 – DEFINITION OF CLASSES OF SUPPLY

IWAT	Class I Water not computed, since square and cube of containers is included in Classes VIIA and II+
IRAT	Class I Rations
II+	Includes Classes II, VI, VII non-square consuming items, VIII, IX and X
IIIG	Motor Gasoline
IIID	Diesel Fuel
IIILUB	All non-Aircraft Lubricants
IIIAJP	Jet Aircraft Fuel
IIIALUB	Aircraft Lubricants
IV	Class IV, Construction Material
V	Class VW, Ground Ammunition
VA	Class VA, Aviation Ammunition
VIIASQ	Square consuming aviation items less unit equipment aircraft
AMVEH	Amphibious Vehicle Square
VIISQ	Other Class VII square consuming items

TABLE 3 — MAF REQUIREMENTS

Class	AE			AFOE MAW				AFOE Force Troops			
	Daily Resupply Rate (MT)	Initial Supply		Daily Resupply Rate (MT)	Initial Supply		Basic Allowance (MT)	Daily Resupply Rate (MT)	Initial Supply		Basic Allowance (MT)
		No. of days	Total (MT)		No. of days	Total (MT)			No. of days	Total (MT)	
IR	130	45	5850	40	60	2400		54	60	3240	
II+	633	30	18990	197	60	11820	15,043	257	60	15,420	7835
IIIG	139	10	1390	55	25	1375		98	25	2450	
IIID	234	10	2340	195	25	4875		218	25	5450	
IIILUB*	87	45	3915	66	60	3460		76	60	4560	
IIIAJP	125	10	1250	696	25	17400		1	25	25	
IV	301	45	13545	94	60	5640		122	60	7320	
V	426	45	19170	48	60	2880	949	9	60	540	73
VA	93	45	4185	445	60	26700		0	60	0	
VIISQ							45,790				97328
VIIASQ							18,045				0
AMVEH							0				1636
TOTAL	2168		70635	1836		7705[illegible]		835		39,005	

*Includes III ALUB

Total MAF Daily Resupply = 4839 MT
Total Initial Supply = 186,690 MT
Total Basic Allowance = 186,699 MT

4.2.2.2 Follow-on Resupply. Follow-on resupply is necessary to continue support of the Forces after initial supply is consumed. Both the assault and the Admin MAF's are resupplied until the end of the mission at the daily rates listed in Table 3. The assault MAF is resupplied with a total of 120 days of supply, and the Admin MAF is resupplied as long as the first MAF. The daily resupply of one MAF is 4839 MT/day.

4.3 MEASURES OF EFFECTIVENESS

A requirement curve can be constructed which represents the total amount of cargo that must be delivered as a function of time to satisfy the scenario specifications. Figure 1 shows representative cumulative requirement and delivery curves for discussion purposes.

Conditions are satisfactory when as much or more cargo is delivered than is required. When the cumulative amount of cargo delivered is less than the cumulative amount required ashore, the scenario specifications are not being met and a shortfall exists. To quantitatively measure the performance of delivering cargo, the following measures of effectiveness are formulated:

$$\text{Total Shortfall} = \quad (\text{Cargo Required} - \text{Cargo Delivered})$$

Only positive terms, i.e., where cargo required > cargo delivered, are summed. Terms where cargo required $\leq$ cargo delivered are not summed since a shortfall does not exist.

$$\text{Average Shortfall} = \frac{\text{Total Shortfall}}{\text{Number of Positive Terms}}$$

The total and average shortfall measure the effectiveness of the ships and transfer craft in meeting scenario requirements. Each mix of ships and transfer craft will generate its own particular delivery curve. When this curve is compared to the requirement curve, the total shortfall can be determined. Thus mixes of ships and transfer craft can be varied and evaluated against average and total shortfall to determine the mixes which best meet scenario requirements.

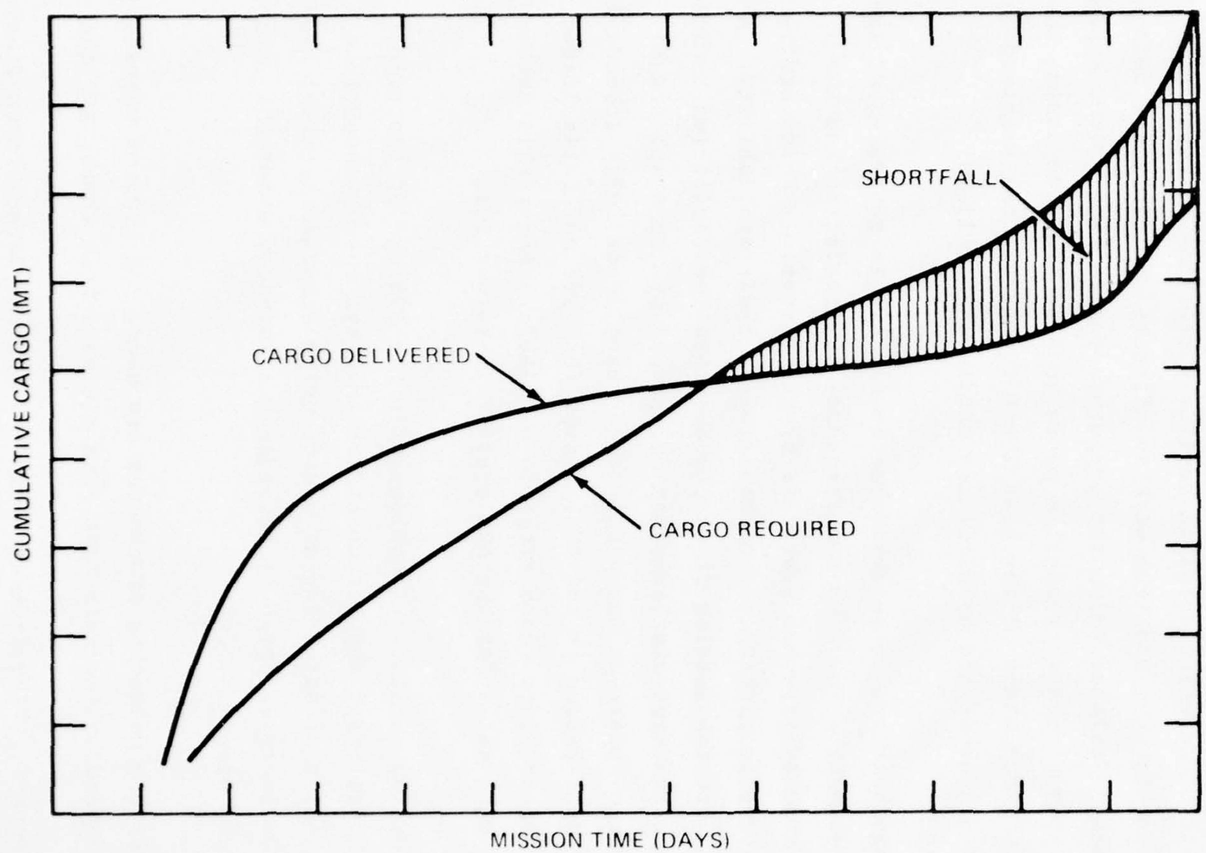

Figure 1 – Representative Cargo Profile Curves

SECTION 5
MERCHANT SHIPPING CHARACTERISTICS AND OPERATIONS

5.1 OVERALL OPERATION

The usage of merchant ships in sealift operations to transport cargo from port to port and from port to offshore positions for delivery ashore has been simulated using the computer program REACT[4] (see Appendix A). The program simulates real-life operations in order to assess the capability of given mixes of merchant ships to deliver the required cargo. The major events generated by REACT are outlined as follows:

The cargo required to be delivered to the AOA is generated at specified ports in CONUS. The time and frequency of generation and the amounts of cargo by type are specified by the scenario. Ships arrive at designated ports to pick up cargo according to their availability. A ship is sent to a port for loading if a) the port has the facilities to load the ship; b) the cargo type available can be carried by the ship; and c) sufficient cargo exists at the port. When the ship is fully loaded, it sails to its destination in the AOA. Ships that are not fully loaded sail to the closest port where cargo is available. After this second loading, the ship sails for the AOA even if it is not full.

The unloading facilities considered in the AOA are of two types: regular port facilities and offshore discharge systems. Conventional procedures consist of unloading at a port using standard material handling equipment. Delivery of cargo is considered terminated after the cargo is unloaded at the pier.

When offshore unloading procedures are used, the type of unloading system will depend on the ship type, the distance from shore, and the

4. Clark, Donna E., "Requirement Evaluated Against Cargo Transportation (REACT) Computer Model User's Manual", In Preparation.

delivery site. The cargo is unloaded from the ship either by the ship's equipment or by external means and is transported to the shore and unloaded. At this point the cargo is considered delivered.

5.2 MERCHANT SHIP CHARACTERISTICS

In this study four merchant ship types are used:

- o Breakbulk
- o Container
- o Ro/Ro
- o Barge Carrier

Each ship type includes large variations in length, displacement, cargo capacity, speed, etc. In a given scenario each ship type has advantages which make it useful in the amphibious mission and disadvantages which impede its usefulness. Table 4 presents a comparison of the different ship types.

5.2.1 Breakbulk Ships

Breakbulk ships usually are equipped with three to five hatches with booms and cranes for cargo handling. The ships are self-sustaining in that exterior handling equipment is not required to load or unload the cargo. Cargo is usually assembled in pallets, is stored vertically in holds, and is hoisted out by the ship cranes. Cargo is usually moved in units of 5 tons or less and receives no protection from the weather. It must therefore be stored in sheltered spots. Spillage and pilferage are always possible.

One of the major advantages of this ship is its self-sustaining characteristic. When the ship arrives at the AOA, it is ready to be unloaded, providing landing craft are available. The breakbulk ship can accommodate most cargo types except containers, but loading and unloading times are longer and cargo capacity is smaller than for the other types of merchant ships.

TABLE 4 – COMPARISON OF MERCHANT SHIP TYPES

SHIP TYPE	ADVANTAGES	DISADVANTAGES
Breakbulk	1. Self-sustaining - no exterior unloading facilities required 2. Adaptable to most military cargo	1. Low to moderate capacity (17-20K MT) and speed (16-20kn) 2. Unitization of cargo only up to pallets 3. Limited new construction
Container	1. Moderate speed (21kn) 2. High capacity (33MT) 3. High unitization of cargo 4. Fast cargo handling rates	1. Incompatible with much military cargo 2. Difficult to unload offshore 3. Requires special transfer craft during off-shore unloading
RoRo	1. Moderate speed (22kn) 2. Moderate capacity (~25MT) 3. Fast handling rate of cargo 4. Self-sustaining	1. Limited availability 2. Ship optimized for RoRo cargo
Barge Carrier	1. Moderate Speed (22kn) 2. High capacity (41KMT) 3. Self-sustaining	1. Limited number available 2. Unloading rate constrained by shipboard crane

The disadvantage of slow unloading becomes less significant in offshore situations, since unloading times of other more productive ship types can be degraded by many conditions. The commercial advantage of container ships on established trade routes has led to decreased use of breakbulk ships, and in the late 1980's breakbulk ships may not be available in any significant number.

5.2.2 Container Ships

These ships handle cargo loaded into standard containers, which are metal boxes with dimensions of 8 feet by 8 feet by 20 feet (32 MT). Many container ships can handle 40-foot containers also, but only 20-foot-long containers are considered in this analysis. Containers are stored internally, and externally on the main deck. Modern container ships carry no cargo handling equipment, and port facilities are required for loading and unloading the ship. The large amount of cargo in one container (from 12-18 ST) has considerably reduced ship loading/unloading time. For example, for general cargo, time has been reduced by approximately one-sixth.

A container ship is generally larger than a breakbulk ship and spends less than 25% of its total cycle time in port; a breakbulk ship spends over 50% of its cycle time in port. Furthermore, containerized cargo is much less susceptible to damage and pilferage. These advantages have induced the merchant ship industry to convert largely to container ships and to gradually phase out breakbulk ships.

The main advantage of container ships is their fast unloading and loading rates. They can thus sail sooner, reducing their turn-around times. Therefore, for port-to-port delivery they are highly efficient. However, the same factors which contribute to high productivity at the port become disadvantageous when unloading offshore. Since most container ships have no cargo handling equipment aboard, external unloading equipment, which can be complex, is required. Futhermore, the use of containers

decreases the possibility of carrying certain types of military cargo, e.g., outsized cargo, large vehicles, and aircraft.

5.2.3 Ro/Ro Ships

Ro/Ro ships have moderate speed and cargo capacity and high cargo handling rates. These ships transport cargo carried by wheeled vehicles, either motorized or on trailers. The cargo is wheeled into the ship on ramps, and containers can be wheeled in on trailers. The cargo can be transported to the desired deck on internal ship ramps and stored. Cargo not on wheels can be carried into the ship by forklifts or sideloaders.

Ro/Ro ships are particularly well-suited for transporting wheeled military equipment. Such heavy cargo is difficult to move on other types of merchant ships. One of the prime disadvantages of Ro/Ro ships is that there are few of them and their procurement for military operation will be difficult.

5.2.4 Barge Carrying Ships

LASH and SEABEE ships fall into this category. These ships have over a 20-knot speed, high cargo capacity, and are self-sustaining. LASH ships carry loaded lighters piled vertically, which are loaded and discharged at the stern by an overhead traveling gantry. In SEABEE ships, the barges are stored horizontally and moved to the stern for unloading by a fixed overhead crane. The barges are towed by warping tugs to other means. No port facilities are required for unloading these ships, although equipment is required for unloading the barges.

5.3 MERCHANT SHIPS AVAILABLE

Merchant ships used in this study are available from two sources: the Sealift Readiness Program (SRP) and the MSC Nucleus Fleet.

Overall there are 128 ships available in this scenario as follows.

	NUMBERS OF SHIPS
SRP	94
MSC Active	14
MSC Reserve	20
TOTAL	128

5.3.1 Sealift Readiness Program (SRP)

The Sealift Readiness Program (SRP) represents a formalized program under which ships can be acquired from US carriers under conditions of less-than-full mobilization. Ships of all types are represented.

For the initial analysis all 94 ships were considered available for use. In subsequent runs only 50% of the SRP ships were used to determine the ability of the degraded SRP fleet to perform the mission. Most of the SRP ships are container and breakbulk ships.

5.3.2 MSC Active and Reserve Ships

The MSC controls approximately 28 ships: half of these ships were considered available for this application. In a recent MSC study, a ready reserve fleet (RRF) of 20 breakbulk ships, in addition to the nucleus fleet, was considered available to provide sufficient sealift capability early in the mission. Table 5 shows the ships available in this study from each source.

TABLE 5 - SHIPS AVAILABLE

SHIP TYPE	SRP	MSC ACTIVE	MSC RESERVE	TOTAL
BREAKBULK	39	10	20	69
CONTAINER	43	0	0	43
RO/RO	2	4	0	6
BARGE CARRYING SHIP	10	0	0	10
TOTAL	94	14	20	128

Since the reserve ships may not be available, situations were examined both with and without them. However, this analysis has shown that a capacity to supplement the active ships in supporting amphibious operations will probably be required, and the reserve ships or a like substitute will be needed.

5.4 AVAILABILITY OF MERCHANT SHIPS

Each ship in the analysis was assigned an availability (listed in Table 6) which represents the time in days after mobilization that the ship will be available at the desired port. These values depend on the geographical location of the ship, whether the ship is loaded, and if loaded how far it is from its destination.

For this study ship availabilities in the SRP were provided to MSC by the various commercial carriers. Since at any given time a particular ship could be anywhere on its trade route, availabilities are only estimates or best guesses. Seven days were added to all

TABLE 6 – SEALIFT ASSETS

Ship Type	Speed (KTS)	Cargo Wt. (L/T)	Cargo Capacity (M/T)	Ship 1/ Type	No. Ships Available: MSC Active Fleet	MSC RRF	SRP	Total Ships	Time Available 2/: East Coast	West Coast
1	19	8400	19498	BB			13	13	D+13, 15, 18, 30, 30	D+4, 7,11, 15, 20, 21, 35, 50
2	21	15219	27055	BB			3	3		D+11, 15, 21
3	21	8544	29760	NSSC			1	1		D+15
4	20	5015	14624	SSC			2	2		D+13, 18
5	21	13500	25344	NSSC			3	3		D+11, 15, 21
6	23	9438	34112	NSSC			2	2		D+14, 18
7	22	20470	43388	LASH			5	5	D+15, 25	D+15, 35, 50
8	23	16789	41415	LASH			5	5	D+21, 28, 40	D+20, 40
9	20	9030	13643	BB			2	2		D+14, 18
10	19	4850	14575	NSSC			2	2		D+30, 40
11	20	8220	18747	BB			8	8		D-7, -3, +3, 7, 10, 14, 17, 20
12	20	7389	14586	NSSC			4	4	D+10, 14, 17, 20	
13	20	10973	21992	BB			4	4		D+10, 14, 17, 20
14	16	7500	26304	NSSC			2	2		D+5, 15
15	17	8300	32768	NSSC			1	1		D+35
16	19	8500	14460	BB	1		9	10	(D-6), D+14, 18, 30, 40	D+15, 30, 32, 40, 42
17	20	10500	29698	NSSC			9	9	D+11, 14, 15, 17, 20, 21, 31, 40, 50	
18	16	4890	13600	NSSC			4	4	D+11, 14, 17, 20	
19	17	10650	37600	SSC			3	3	D+11	D+15, 20
20	24	17000	44320	NSSC			2	2	D+30, 40	
21	33	24435	58375	NSSC			8	8	D+21, 31, 41	D+21, 31, 40, 45, 50
22	18	7000	11600	BB	1(EC)	6(3EC/3WC)		7	(D-10, -10, -10, -10)	(D-10, -10, -10)
23	22	10000	16072	BB	8(6EC/2WC)	14(7EC/7WC)		22	(7@D-10, -8, -6, +5, 10, 15, 20)	(7@D-10, D day, D+10)
24	24	17011	47950	RO/RO	2		2	4	(D-10, -8) D day, +10	
25	19	10000	20450	RO/RO	2			2		(D+10, 20)
Total Ships:					14	20	94	128		

1/BB = Break Bulk or General Cargo
NSSC = Non-Self-Sustaining Container Ship
SSC = Self-Sustaining Container Ship
LASH = Lighter Aboard Ship
RO/RO = Roll-On/Roll-Off Ship
EC = East Coast
WC = West Coast

M Day = D-23
D Day = M+23

2/( ) Indicates MSC Active and RRF ships

availabilities to represent a delay time in calling up the ships due to administrative procedures. The active and reserve ships are available for loading at port much earlier than those of the SRP. Most of the MSC ships (under Navy control) are available at D-10 i.e., ten days before D-Day. Mobilization M-Day, occurs at D-23, twenty-three days before D-Day.

SECTION 6
OFFSHORE DISCHARGE OPERATION

Delivery of Marine Corps Forces to conventional ports reduces the flexibility of the operation. Conventional ports are very vulnerable to attack. If a port were severely damaged or destroyed, the means of delivering the cargo would be eliminated and the mission would most likely have to be aborted. When cargo is delivered from offshore positions without the use of built-up port facilities, the vulnerability of the operations is decreased. The Marine Corps desires the flexibility of unloading at ports or offshore, depending on the nature of the contingency. The purpose of this investigation was not to design the hardware required to unload ships offshore, but to examine the processes and general equipment involved. Systems used in the unloading process were assumed to be available in the 1980's when required.

6.1 DELIVERY OF CARGO TO PORTS VS OFFSHORE DELIVERY

Other than barge carriers and breakbulk ship, all merchant ships are designed to be unloaded and loaded only at conventional ports. Even the Ro/Ro, which does not require external handling equipment, is designed for port operations.

Although experience has indicated that most types of merchant ships can be offloaded offshore, a deterioration in productivity is involved. This deterioration can be minimized by designing an efficient unloading, handling, and transportation system to deliver the cargo ashore. Low offshore unloading rates for high-productivity ships, e.g., container ships, may negate the advantages of these ships.

6.2 SHIP UNLOADING EQUIPMENT

Table 7 summarizes additional unloading equipment required by the four ship types in the offshore discharge operation. The container ships

TABLE 7 – OFFSHORE DISCHARGE REQUIREMENTS

SHIP TYPE	UNLOADING EQUIPMENT	TRANSFER CRAFT
Breakbulk	Has its own	Landing Craft, Causeway Ferry
Container	Unloading platform or Unloading Ship	Causeway Ferry
RoRo	None -- cargo rolled out (needs intermediate platform between ship and causeway ferry)	Causeway Ferry
Barge Carrier	None -- ship unloads barges or lighters with cargo preloaded	None, if ship carries warping tugs; otherwise propulsion is required

are the only type that require extensive cargo handling equipment, which could consist of either a stationary platform with a crane or a ship with a crane or boom on it. In this analysis, detailed descriptions of unloading systems were not necessary. The operations and the productivity of the systems were sufficient to characterize the unloading operation. An intermediate platform or bridge will probably be required when unloading RO/RO ships.

6.3 TRANSFER CRAFT

When ships are unloaded, means for moving the cargo to the shore are required. Often more than one type of transfer device can be used for a particular ship type; in such cases, the most productive means was chosen. The modes of transportation are:

- Landing Craft - e.g. LCU(1610), LCM(8), LCM(6)
- Causeway Ferry
- Barges

Landing craft are self-propelled craft which are loaded alongside the ship and can beach ashore to unload. They are characterized by speed, cargo capacity, and loading and unloading rates. Landing craft are used mostly with breakbulk ships, but they can also be used to transport containers.

Causeway ferries are made from individual causeway sections (usually three) joined together. Either an outboard motor or a warping tug is used for propulsion. Because of their large surface area, causeway ferries generally transport containers and Ro/Ro cargo, which simply rolls down a ramp from the Ro/Ro ships onto the causeway ferry.

Barges (referred to as lighters) are carried by the LASH ships and are preloaded with cargo, as are barges carried by the SEABEE ships. Since these ships carry their own transfer craft and warping tugs, no additional ship unloading equipment is required when using these ships to delivery cargo from an offshore position.

6.4 SHORE EQUIPMENT

After the transfer craft move the cargo ashore, it then must be unloaded. The equipment used to unload the transfer craft depends on the types of craft and cargo moved.

6.4.1 Unloading Landing Craft

Landing craft carrying breakbulk cargo to the beach are unloaded by forklift trucks which deposit the cargo in a designated storage or pickup area. The number of forklifts required depends on the rate at which cargo is delivered to the beach. Landing craft carrying containers are unloaded by a crane at the beach.

The Advanced Amphibious Landing Craft (AALC), an ACV type with soft sidewalls, represents a future possibility. It can move onto the beach and be unloaded by forklifts at the bow and stern gates. Consequently its unloading rate is nearly twice that of a conventional landing craft.

6.4.2 Unloading Causeway Ferries

When surf conditions and beach gradient allow, the causeway ferry (CF) can be beached for unloading and either a crane or container forklift can unload the containers. Ro/Ro cargo simply rolls from the CF to the beach. In rough surf, the CF can be unloaded on a causeway constructed over the surf. A crane unloads the containers onto a tractor trailer which delivers them ashore. Ro/Ro cargo moves over the jacked-up causeway and then ashore.

Two methods of loading containers on a CF were considered. In one method, called mobile loading, the containers are loaded on tractor-trailers which are themselves loaded on the CF. The tractor-trailer moves off the CF and is then unloaded ashore. In the second method, called deck loading, the containers are loaded directly on the (CF) and then unloaded by crane either at the beach or on tractor-trailers on

the jacked-up causeway for delivery to the beach. In this analysis deck loading of the causeway ferry was assumed.

SECTION 7
PORT-TO-PORT ANALYSIS

Four ship mixes for transporting cargo from CONUS ports to the delivery port were examined. Cargo was considered delivered when unloaded at port; the required unloading equipment was assumed available.

7.1 DESCRIPTION OF MIXES

The merits of four merchant ship mixes consisting of the ship types discussed previously were compared. The effects of earlier ship availabilities, and the effect of utilizing the reserve ships were also examined. The four mixes described below included ships from the SRP and an equal number of MSC active and reserve ships (known as the ready reserve fleet (RRF)).

- All-Ship Mix: All ship types were available for use

- Container Mix: Only container ships

- Breakbulk Mix: Only breakbulk ships

- No-Container: All ship types but container ships

To vary the number of ships available in each mix, a simple addition was made to REACT to input a value called the "availability limit." Any ship with an availability greater than the availability limit will never be used, i.e., the ship will never become available. When the availability limit is increased, more ships are available; when it is decreased, fewer ships are available. Table 8 shows the ships that are available for various availability limits for each of the four mixes.

TABLE 8 – MERCHANT SHIP CONFIGURATIONS

Ship Type	Ship Type No.	Container Mix				All-Ships Mix			BB Mix		No Cont. Mix
		Availability Date (A)									
		A=30	A=32	A=45	A=100	A=30	A=32	A=45	A=45	A=100	A=45
BB	1					4	6	9	9	13	9
BB	2					1	2	3	3	3	3
BB	3	1	1	1	1	1	1	1	1	1	1
Cont	4	1	1	2	2	1	1	3			
Cont	5	1	2	3	3	1	2	2			
Cont	6		1	2	2		2	2			
LASH	7						2	7			3
LASH	8							3			3
BB	9						1	2	2	2	2
Cont	10				2						
BB	11					5	6	8	8	8	8
Cont	12	1	2	4	4	1	2	4			
BB	13					1	2	4	4	4	4
Cont	14	1	2	2	2	1	2	2			
Cont	15				1						
BB	16					2	2	5	6	9	5
Cont	17	1	4	7	10	1	4	7			
Cont	18	1	2	4	4	1	2	4			
Cont	19	1	2	3	3	1	2	3			
Cont	20				2						
Cont	21			2	8			2			
BB	22	7	7	7	7	7	7	7	7	7	7
BB	23	22	22	22	22	22	22	22	22	22	22
Ro/Ro	24	3	3	4	4	3	3	4	4	4	4
Ro/Ro	25	2	2	2	2	2	2	2	2	2	2
TOTAL		42	51	65	79	55	73	106	68	75	73

Initially, a value of 7 days was added to each ship's availability to reflect administrative delays in calling up a ship and the time for response. Several REACT runs were made varying this delay time to examine its effect. Other REACT runs were made varying the availability limits.

7.2 PORT-TO-PORT RESULTS

Two graphs are presented for each computer run. The first graph (Figure 2, Appendix B for example) consists of the cargo delivered curve and the requirement curve. The cargo delivered curve represents the cumulative amount of cargo delivered to the delivery port as a function of time. The requirement curve represents the cumulative amount of cargo required at the delivery port as a function of time. Thus the graph shows, for any mission time, whether the cargo requirements are being satisfied. The second graph (Figure 3, Appendix B for example) shows the percentage of required cargo delivered.as a function of time.

The requirement curve, Figure 2, was developed based on the assumption that the assault echelon (AE) was required at D+7 (seven days after D-Day) or M+30 (30 days after mobilization), and the assault follow-on echelon (AFOE) 5 days after the AE, i.e., at D+12. Since the requirement seemed unrealistically rigid, it was subsequently relaxed and the AFOE was considered required between D+12 and D+22 (M+35 to M+45), i.e., between 5 and 15 days after the assault. Therefore the cargo requirements shown on the graphs at D+12 need not be satisfied until D+22.

The following sections describe the different computer runs. The reserve fleet is used in all cases unless otherwise specified. The number in parenthesis proceeded by Av in the section titles is the availability limit used in the run. The standard mixes include the reserve fleet and the normal seven-day delay incorporated in the availabilities.

A word of explanation is necessary in interpreting the results. The total requirement curve (representing the total force cargo requirement) was developed by summing the individual requirements for

- o AFOE, required at D+22
- o Admin MAF, required at D+37
- o Resupply, required after D+15

In some cases the total force requirement for delivered cargo was met but the individual requirement for either the AFOE or the Admin MAF was not met. For example, in cases CT5, CT6, AL2, AL3, and AL4 total requirements were met at D+22 but the individual AFOE requirement was not met, indicating that the requirement for either the Admin MAF or resupply was exceeded at the time. In cases C4 and NC1 total requirements were met at D+37, but the individual Admin MAF requirement was not met, indicating that the resupply requirement was exceeded. In such situations the ships carrying the excess cargo could be redirected to provide additional lift for either the AFOE or the Admin MAF. Therefore, if the total requirement is met, it is assumed that the individual requirement can be met by reallocating ships if necessary.

7.2.1 Standard Container Mixes

Results for the standard runs are graphed on Figures 2 though 9. These and all other figures in this section can be found in Appendix B.

7.2.1.1 Case CT1 (Av 30). Sufficient numbers of ships to perform the mission are not available. Cargo generated is always greater than the cargo being shipped with a continuous buildup of cargo at the CONUS ports.

The amount of cargo required ashore is always greater than the amount of cargo delivered. Since only 71% of the AFOE is delivered by D+22 and 27% of the Admin MAF is delivered by D+37, this case is unacceptable (Figures 2 and 3).

7.2.1.2 Case CT2 (Av 32). Cargo shipped is nearly as great as the cargo generated especially after D+50. However, there are still insufficient ships available. Up to D+57 requirements are not met except between D+27 and D+32. After D+57 all cargo required is delivered. Only 78% of the AFOE and 42% of the Admin MAF is delivered on time (Figures 4 and 5).

7.2.1.3 CASE CT3 (Av 45). The scenario requirements are met from D+24 to D+102 (except at D+37); after D+102 not all the cargo required is delivered. The percent of required cargo delivered is generally higher in this case than in CT2, with exceptions at D+37 and short periods at the end of the mission. Eighty-one percent of the AFOE and 80% of the Admin MAF is delivered on time (Figures 6 and 7).

7.2.1.4 Case CT4 (Av 100). Requirements are met completely by D+24 and continue to be met until the end of the mission. Eighty-one percent of the AFOE and 80% of the Admin MAF is delivered on time. The AFOE is required between D+12 and D+22, but is delivered by D+27, although total requirements are met by D+24 (Figures 8 and 9).

7.2.2 Availability Limit Change

In these runs the 7-day delay added to all ship availabilities to simulate lead time and administrative delays has been eliminated (see Figures 10 through 13).

7.2.2.1 Case CT5 (Av 45). Most of the requirements are met by D+19 compared to D+24 in Case CT3 (the equivalent case with the delay).

As in Case CT3 the requirements are not fully met at D+37, indicating that the complete Admin MAF is not delivered on time. At D+22 when the AFOE is required, 96% of required cargo is delivered, compared to 80% in Case CT3 (Figures 10 and 11).

7.2.2.2 Case CT6 (Av 100). As in run CT5 the requirements are met by D+19 and 96% of the AFOE is delivered by D+22 (Figures 12 and 13).

7.2.3 Container Runs Without RRF

In these runs (Figures 14 to 17) the 20 breakbulk ships of the RRF, which are generally available at D-10, were not used. The results of the runs indicate the effects of not using a Ready Reserve Fleet.

7.2.3.1 Case CT7 (Av 45). Except at D+32 requirements are not met until D+67. Neither the AFOE nor the Admin MAF was delivered on time. Only 51% of the AFOE is delivered by D+22, and 46% of the Admin MAF by D+37, a far from satisfactory situation (Figures 14 and 15).

7.2.3.2 Case CT8 (Av 100). Except for D+32 requirements are not met until D+47. Neither the AFOE nor the Admin MAF is delivered on time. Only 51% of the AFOE and 46% of the Admin MAF are delivered when required. However, the performance in this case is better than in Case CT7, for the requirements are met sooner (D+47 instead of D+67) (Figures 16 and 17).

7.2.4 Conclusion: Container Mix

In the standard runs the best case is CT4, where 79 ships were utilized and requirements were met by D+24. The AFOE is required between D+12 and D+22, but is delivered by D+27. The Admin MAF is fully delivered when required, i.e., at D+37. Case CT3, in which much of

the cargo required is delivered after D+24 but not as much as in case CT4, requires only 65 ships, 14 ships fewer than CT4.

Eliminating the 7-day delay in calling up the ships results in meeting the requirements about 5 days sooner. The best performance of all nine container cases came from CT6 (Av 100) where the 7-day delay was eliminated. The AFOE is delivered on time since all requirements are fully met after D+19. The advantage of either eliminating this delay time or at least reducing it, possibly by streamlining the call-up procedure, is evident. If the SRP can make ships available sooner by reducing the call-up time, satisfying the requirements 5 days earlier would be desirable. Since increasing the availability limit from 45 to 100 days (Cases CT5 and CT6) made little difference in performance, Case CT5 is the preferred case.

The use of the RRF has a large impact on the ability to meet the requirements on time. The shortfall of cargo delivered early in the mission cannot be entirely compensated for by increasing the participation of the SRP ships. The problem is not in the number of ships but in obtaining them early enough. The SRP ships will not help in this case, since they are generally not available until D+10 or after, while the reserve ships, when used, are available at D-10. The additional ships available in Case CT8, as compared to CT7, did not enable the AFOE to be delivered sooner, but did decrease the time to meet requirements.

The use of the RRF was shown to be beneficial in meeting requirements early in the mission and indicates that the RRF or a similar substitute should be implemented. Unless enough ships are available early (such as the RRF), the scenario requirements cannot reasonably be met.

7.2.5 Standard All-Ship Mix

The following runs use the standard availabilities with the normal 7-day delay and the 20 RRF ships (Figures 18 to 23).

7.2.5.1 Case AL1 (Av 30). Requirements are satisfied from D+24 to D+34 and from D+57 to the end of the mission by 55 ships. The AFOE is delivered 2 days late, for at D+22 85% of the AFOE is delivered. The ships are unable to deliver the Admin MAF when required, for at D+37 only 53% is delivered (Figures 18 and 19).

7.2.5.2 Case AL2 (Av 32). The requirements are satisfied from D+22 to the end of the mission, except at D+37 when the Admin MAF is required but only 85% delivered. By D+22 89% of the AFOE is fully delivered. A total of 73 ships was used (Figures 20 and 21).

7.2.5.3 Case AL3 (Av 45). Requirements are satisfied from D+22 to the end of the mission (with a minor exception at D+102). By D+22 89% of the AFOE is delivered and by D+37, 100% of the Admin MAF is delivered by the fleet of 104 ships (Figures 22 and 23).

7.2.6. Availability Limit Change

The All-Ship mixes were run without the 7-day delay in availability (Figures 24 to 27).

7.2.6.1 Case AL4 (Av 32). Requirements are first met at D+18 and continue to be met until the end of the mission except for the interval between D+36 and D+47. Performance at the beginning of the mission was better in this case than in the equivalent case (AL2) with the delay time. In Case AL2 the AFOE is 89% delivered at D+22 while in this case it is completely delivered. However, from D+37 to D+52 and at D+97

Case AL4 is not as good as Case AL3. Case AL2 delivers 85% of the Admin MAF, while AL4 delivers only 60% at D+37 (Figures 24 and 25).

7.2.6.2 Case AL5 (Av45). Case AL5 shows a better response than does AL3 from the beginning of the mission to D+22, but from D+32 to D+47 it is not as good. Case AL3 delivers 89% of the AFOE by D+22 and 100% of the Admin MAF when required (Figures 26 and 27).

7.2.7 All-Ship Runs Without RRF

The following cases did not include the RRF (Figures 28 to 31).

7.2.7.1 Case AL6 (Av32). Requirements are not met until D+67 (with one exception at D+22). Serious degradation occurs without the RRF as compared to Case AL2 with the RRF. At D+22 only 63% of the AFOE is delivered and at D+37 only 37% of the Admin MAF is delivered (Figures 28 and 29).

7.2.7.2 Case AL7 (Av 45). Requirements are met by D+27 and continue to be met until the end of the mission. In the equivalent case (AL3 with RRF) the requirements are met by D+22. Serious degradation occurs in AL7 before D+27. In case AL3 89% of the AFOE is delivered by D+22 while in Case AL7 only 66% is delivered (Figures 30 and 31).

7.2.8 Conclusion: All-Ship Mix

The most effective standard case is AL3 using 103 ships; case AL2 using 73 ships is almost as good in meeting the requirements. Case AL2 delivers less cargo at D+37 but actually performs better than AL3 toward the end of the mission (Figure 20). From a cost effectiveness point of view Case AL2 is preferred over AL3. Case AL2 delivers 83% of the Admin MAF, using 30 fewer ships than AL3 which delivers the admin MAF on time.

When all ship availabilities are reduced by 7 days, more cargo is delivered earlier in the mission. However, this earlier delivery is at the expense of the Admin MAF, whose delivery is degraded. Some of the ships that delivered the Admin MAF in Cases AL1 through AL3 are used in cases AL4 and AL5 to deliver the AFOE because they are available earlier. Since they are available before the Admin MAF is generated, they are committed to transport any cargo still in port, and thus transport the AFOE. However, if these ships are available only after the Admin MAF is generated, they pick up both the AFOE and Admin MAF, thereby reducing the early delivery of the AFOE (Cases A1 to A3).

The elimination of the RRF substantially reduces the lift capability of the all-ship configurations.

7.2.9 Standard Breakbulk Mix

7.2.9.1 Case BB1 (Av45). Requirements are first met between D+25 and D+36, and then are met from D+54 to the end of the mission using 68 ships (Figures 32 and 33). At D+22 84% of the AFOE is delivered and at D+37, 77% of the Admin MAF is delivered.

7.2.9.2 Case BB2 (Av 100). Requirements are first met between D+25 and D+36 and are met from D+47 to the end of the mission using 75 ships (Figures 34 and 35).

All breakbulk ships are used in Case BB2, in which 84% of the AFOE is delivered by D+22 and 77% of the Admin MAF by D+37. Neither case BB1 or BB2 meets the requirements on time.

7.2.10 Availability Limit Change - Case BB3 (Av 100)

Requirements are met between D+21 and D+36 and from D+47 to the end of the mission (Figures 36 and 37). Eliminating the 7-day delay

causes the requirements to be met 4 days earlier. The AFOE is completely delivered by D+22 and 68% of the Admin MAF is delivered by D+37.

7.2.11 Breakbulk Runs Without RRF - Case BB4 (Av 100)

The reserve fleet was not used in this run (Figures 38 and 39). The elimination of the RRF markedly degrades performance in Case BB7; the requirements are not met until D+117, which represents unacceptable performance.

7.2.12 No-Container Mix - Case NC1 (Av 45)

Requirements are fully met by D+32. The AFOE is completely delivered by D+22, and 67% of the Admin MAF is delivered by D+37 (Figures 40 and 41).

7.3 OVERALL CONCLUSION

Table 9 summarizes the best results discussed in the last section. Columns 4 and 5 give the percentages of AFOE and Admin MAF delivered at the required times. Column 6 shows the day that requirements are first met; any value less than or equal to D+22 indicates that the AFOE was delivered on time. In some cases, an interval occurs after the time given in column 6 when the requirements are not met. The limits of this interval are given, when applicable, in columns 7 and 8.

7.3.1 Standard Runs

The standard configurations are ranked in their ability to meet the scenario requirements as follows:

TABLE 9 – SUMMARY OF BEST RESULTS

Configuration	Run Type	Availability	AFOE %Delivered By D+22	Admin MAF % Delivered By D+37	Require-ments First Met	Interval, Requir. Not Met (if applicable)		Case
						Lo	Hi	
Container	Standard	100	81	80	D+24			CT4
Container	No Delay	100	96	73	D+19			CT6
Container	W/o RRF	100	51	46	D+47			CT8
All-Ship	Standard	32	89	85	D+22			A12
All-Ship	No Delay	32	100	60	D+18	D+36	D+47	A14
All-Ship	W/o RRF	32	63	58	D+67			A16
Breakbulk	Standard	100	84	77	D+25	D+36	D+47	BB2
Breakbulk	No Delay	100	100	68	D+21	D+36	D+47	BB3
No-Container	Standard	45	100	67	D+23			NC1

1 - All-Ship

2 - Container

3 - No-Container

4 - Breakbulk

Generally, container ships are available later than other types of ships so containership mixes as a whole suffer in performance, although many of the container ships individually are very efficient. Table 9 shows that the All-Ship mix is generally superior to the Container mix. The AFOE and the Admin MAF are delivered sooner and the total requirements are also met earlier in the mission. The Breakbulk mix is generally inferior to the All-Ship or Container mixes, in meeting the requirements except in the delivery of the AFOE. This result was due to the earlier availabilities of breakbulk ships, which are generally smaller and have slower speeds and lower cargo handling rates than the other ship types. The No-Container mix is interesting, for the percent of the AFOE delivered is greatest of all standard runs. However, the percent Admin MAF delivered is the lowest of all runs due to early availability of ships.

It should be noted that ship availability is a significant factor in the time at which the requirements are met. Any change in ship availabilities could change the above ranking. The input ship availabilities used were the best estimates received informally from US carriers.

One reason that the All-Ship mix was the best is that it contains a mixture of all types of merchant ships, i.e., breakbulk, container, Ro/Ro, and LASH. All types except breakbulk ships are fast in unloading and have short turn-around times. The breakbulk ships are slow but usually were available sooner than the other ship types.

The container ships are available later in the mission than the breakbulk ships and many ports where cargo is picked up have limited container ship berths, e.g., Sunny Point has only one. Any waiting at ports negates the fast cycle time of the high productivity container ships. Since berths are usually available for the types in the All-Ship mix, the advantage of the diversification in the All-Ship configuration can be seen.

The No-Container mix contains proportionately more ships that are available earlier in the mission. The container ships with later availabilities are not included. Because more ships are available earlier, a large proportion of ships (compared to the other cases) is assigned to carry AFOE cargo, thereby reducing the ships available for transport of the Admin MAF.

In case NC1, the No-Container mix, requirements are fully met by D+32 but only 85% of the Admin MAF is delivered by D+37. Actually, although the total tonnage value delivered satisfies the total requirement, the tonnage requirement of the Admin MAF has not been satisfied. The total amount of resupply has exceeded requirements and obscured the deficit in Admin MAF requirements. The results indicate that enough ships exist to carry the total tonnage. Therefore, when total requirements are met before D+37, ships can be reallocated from resupply to the Admin MAF. Then the total Admin MAF can be delivered on time.

7.3.2 Advanced Delivery

In all cases, eliminating the 7-day delay results in a higher percentage (an average of 14% higher) of the AFOE delivered by D+22. However, more ships must be committed to the AFOE to transport this extra 14% (98,000 MT). Since most of the ships were originally used to transport the Admin MAF, the delivery rate of the Admin MAF will decrease due to the reallocation of ships. At D+37 the amount of the Admin MAF delivered is reduced by 14% (or 60,000 MT). Thus the desirability of eliminating the 7-day delay is questionable and must be weighed against

the priorities of the scenario. If the AFOE is most important, then a decrease in delay time is desirable. If the Admin MAF is more important, then the delay should not be reduced.

7.3.3 Ready Reserve Fleet (RRF)

Severe degradation in the scenario response time occurred in all cases when the RRF was eliminated. The Container and All-Ship mixes exhibit poor performance when compared to the standard runs with the RRF. The Breakbulk mix case was totally unacceptable.

SECTION 8
COMPARISON OF THE REACT AND TRADES MODELS

Over-the-beach cases were simulated with a new program named TRADES.[5] This program is similar to REACT up to the delivery of the cargo. Where REACT considers only port delivery, TRADES can also consider unloading the ships offshore, transporting the cargo to the beach, and then unloading the cargo. Using TRADES makes it possible to examine different combinations of landing craft and causeway ferries for cargo delivery ashore to obtain optimal mixes for a given scenario.

8.1 PORT-TO-PORT COMPARISON

Since a new program was used in this analysis, it was necessary to correlate the results of the two models for the same input and examine any deviations. Because TRADES was programmed along the lines of REACT, the results should be similar.

A case representing the least number of ships meeting the requirements was chosen from each ship mix for comparison, as shown in Table 10. Table 11a presents the results of running REACT with these mixes. Tables 11b and 11c present the results of the same mixes run with identical scenarios using the TRADES model in the port-to-port operation. Table 11 shows that the ranking by shortfall is in the same order and that the percent deviations in shortfall are similar for both models. Since this analysis compared relative effectiveness, the slight deviations in the results from the two models will not affect the final results and conclusions. Consequently, the use of TRADES in this section can be considered an extension of the REACT analysis in the last section and the conclusions drawn from REACT can be considered borne out by TRADES.

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5. Friedenberg, Paul E., and Raymond E. Melton, "Transportation and Delivery of Equipment and Supplies (TRADES) Computer Model User's Manual", In preparation.

TABLE 10 – OPTIMAL SHIP MIXES

Mix	Availability Limit	No. of Ships Used
All-Ships	32	73
Container	100	79
No-Container	45	73
Breakbulk	100	75

TABLE 11 – PORT-TO-PORT RUNS

TABLE 11a- REACT Runs - Standard Availabilities

Mix	Avail.	Shortfall (MT)	% Deviation From Lowest Shortfall	Ranking Least Shortfall
All-Ship	32	464,000	1.00	1
No-Container	45	505,000	1.09	2
Container	100	588,000	1.27	3
Breakbulk	100	666,000	1.44	4

TABLE 11b- TRADES Runs - Standard SRP Availabilities

All-Ships	32	506,451	1.00	1
No-Container	45	598,509	1.18	2
Container	100	664,216	1.31	3
Breakbulk	100	832,469	1.64	4

TABLE 11c- TRADES Runs - ALL Ship Availabilities = 7

All-Ship	32	13,987
No-Container	45	-0-
Container	100	54,682
Breakbulk	100	-0-

Intuitively, one feels that the Container mix should have given the best results because of the rapid handling rates of the container. Since it is not completely clear why the All-Ship mix gave better results than the Container mix, another run was made in which the availabilities of all the ships were initialized to 7 days. Thus all the ships were available at the same time at the beginning of the mission, ready to pick-up cargo as it was generated. The purpose of these runs was to examine each configuration without including ship availability as a factor.

Table 11c shows the results. The shortfalls of the No-Container and Breakbulk mixes are zero. The All-Ship mix shortfall is small and the Container mix is larger but still small in comparison to shortfalls shown in Table 11b. The Container mix shortfall is caused by the queuing of ships at the limited number of container berths. If sufficient berthing existed, the Container mix shortfall would be zero. Thus the mixes give similar results when the availabilities are initialized to 7 days.

8.2 CONCLUSION: PORT-TO-PORT COMPARISON

The overriding factor in the performance of the various merchant ship mixes in meeting scenario requirements is ship availability. The sooner a ship is available the better, regardless of type. A slow breakbulk ship will give faster delivery than a container ship if the breakbulk ship is available 20 days earlier. Fast efficient ships lose their advantage in early response if they are not available early in the mission. If a container ship is available at the same time as a breakbulk ship, the container ship performance will be superior. Even if the container ship is available a few days later than the breakbulk ship, it will have a faster cycle time. However, as the difference in availabilities approaches 10 days, the advantage of the container ship starts to decrease.

An example will illustrate. Consider a breakbulk and a container ship with the following characteristics:

Ship Type	Load/Unloading Rate (MT/hr)	Speed	Cargo Capacity (MT)
Breakbulk	225	18	20,000
Container	1,448	23	20,000

Distance = 5000 nmi

The total time to load, transport, and unload cargo is

$$\text{Total BB Cycle Time} = \frac{1}{24}\left[\frac{2\ (20{,}000)}{225} + \frac{5{,}000)}{18}\right] = 19 \text{ days}$$

$$\text{Total Container} = \frac{1}{24}\left[\frac{2\ (20{,}000)}{1{,}448} + \frac{5{,}000)}{23}\right] = 10 \text{ days}$$

The first term in the brackets represents the time to load and unload the ships and the second term the transport time in hours. Both are divided by 24 to obtain days. The difference in the two cycle times is 9 days. Of course many container ships can carry more than 20,000 MT, but this simple analysis indicates that, if a container ship is not available for 9 days or more after a breakbulk ship, the container ship loses its advantage. Generally the largest shortfall occurs early in the mission due to late availability of ships.

Therefore, Table 11b shows that much of the difference in shortfall is due to the initial ship availability. However, the values of the availabilities should not be underestimated. The availabilities represent the best estimates of the commercial carriers. Consequently, although container ships are highly productive, the availabilities specified do not allow capitalizing on their advantages in the scenario.

SECTION 9
OVER-THE-BEACH-RESULTS

The TRADES Model was used to determine the transfer craft required to deliver the cargo to the shore. The model was used in the same way that REACT was used except that, instead of cargo being delivered to the port, the cargo is unloaded from the ship, delivered ashore, and then unloaded. The four best cases of each mix listed in Table 10 were used.

To simplify the analysis only one type of landing craft was used to carry breakbulk cargo, although provisions for two types exist in the model. Thus a direct comparison of landing craft can be made among the four mixes, which would be difficult if two types were used.

A series of runs was made with each mix in which the numbers of landing craft (LCM(8)'s) and causeway ferries were varied to obtain optimal configurations. Figures 42 to 49 are graphs of the results. An optimal configuration is defined as one in which the shortfall is a minimum and the ships do not wait more than one day offshore to be unloaded. The last constraint was imposed to prevent the ships from waiting unreasonable lengths of time to unload cargo. There is evidently a tradeoff between ship waiting time to unload and number of landing craft used. As the number of landing craft decreases, the time the ships wait for unloading increases.

The results of TRADE's runs for the four mixes are presented in Table 12, which lists the shortfall and ranking of the mixes. The ranking is similar to that of the port-to-port results in Table 11, but the Container mix now ranks second and the No-Container mix now ranks third. The advantages of container delivery offshore are shown. Since the availabilities have not been changed, the Container mix is more efficient in the over-the-beach situation. Shortfall is intimately related to ship availability, although shortfall is not necessarily a measure of individual ship effectiveness.

TABLE 12 – OVER-THE-BEACH RESULTS USING TRADES

Config.	Shortfall (MT)	% From Smallest	Rank
All-Ship	1,035,009	1.00	1
No-Container	1,261,506	1.22	3
Container	1,231,569	1.19	2
Breakbulk	1,638,060	1.58	4

TRANSFER CRAFT RESULTS

	No. LCM8	Caus. Fer.	Forklifts	Shoreside Cranes	Unloading Platforms
All-Ship	112	6	42	3	3
No-Container	128	2	48	0	0
Container	104	12	39	6	6
Breakbulk	136	2	51	0	0

In order to compare the four mixes in over-the-beach operations, the number of transfer craft required was examined (see Table 12). Breakbulk cargo is transferred by LCM(8)'s from breakbulk ships to the shore where the cargo is unloaded by forklifts. Containerized cargo is unloaded from container ships by unloading platforms and transferred to waiting causeway ferries which proceed to the shore where the containers are unloaded by crane.

The Container mix requires the least number of landing craft, i.e., 104, but requires the most causeway ferries (CF) since most of the cargo is containerized. When cargo is unloaded at a distance of 1 mile offshore, the amount of cargo delivered ashore is independent of the type of landing craft used, i.e., LCM(8)'s, LCM(6)'s, or LCU(1610)'s are interchangeable because the loading/unloading times (the unloading/loading rates are the same for all landing craft) are much greater than the transportation times. LCM(8)'s, LCM(6)'s and LCU(1610)'s all give the same results.

The All-Ship mix, which contains a number of container ships, requires 112 LCM(8)'s and 6 causeway ferries to transport cargo to the beach. The All-Ship mix requires only 8 more landing craft than the Container mix (8% increase) and requires 6 fewer CF (50% decrease). From a resource point of view, the All-Ship mix, which has lower total shortfall, is more cost-effective than the Container mix.

The two mixes which do not utilize container ships are the Breakbulk and the No-Container mixes. These mixes do not require unloading platforms, require only 2 CF's compared to 6 for the All-Ship mix and 12 for the Container Mix, but do require more landing craft (on the average of 22% more). Between these two mixes, the No-Container mix is preferable. It has a much lower shortfall and requires fewer craft than the Breakbulk mix because LASH ships, which carry their own transfer craft, are utilized in the No-Container mix.

If there is no constraint on resources, the All-Ship mix is the best for it has the lowest shortfall. However, the No-Container mix requires 4

fewer CF's than the All-Ship mix and no unloading platforms, although it does require 16 more landing craft. The choice among mixes will be based on available resources. However, if the Container mix is required because of changes in the commercial fleet, it will be necessary to acquire about 12 unloading platforms. The necessary landing craft required are presently available.

SECTION 10
STUDY CONCLUSIONS AND RECOMMENDATIONS

10.1 CONCLUSIONS

- o <u>All-Ship Mix</u>. Of the four mixes examined this one gave the best performance. The mix contains all four types of merchant ships: container, breakbulk, Ro Ro, and barge-carrying ships. Especially important are the self-sustaining characteristics of the barge-carriers, i.e., LASH and SEABEE; the high productivity and convenience of the container ships; and the early availability of the breakbulk ship. (See section 7.1 for a definition of these mixes).

- o <u>Container Mix</u>. The performance of this mix would have been better but for the late availabilities of the ships. Ship scheduling is very important; time spent waiting to unload or load negates the high productivity of container ships. Container ships require the largest amount of equipment for offshore delivery of cargo.

- o <u>Breakbulk Mix</u>. This mix provides good early response, but low productivity decreases performance during most of the mission. Breakbulk ships are economical to use in an offshore operation because of their self-sustaining capability.

  <u>No-Container Mix</u>. This mix performs nearly as well as the container mix. The lack of container ships did not materially affect cargo delivery since other highly productive ships (e.g., Ro/Ro and barge carrier) were present.

- o Because of the limited number of ships available early in all the mixes, there is trade-off between prompt delivery of the AFOE and of the Admin MAF.

Breakbulk ships will still be available in the 1980-1985 period but their number will be rapidly decreasing through the later part of the decade. Unless an alternative form of shipping is available for offshore discharge operation, it will be necessary to use container ships with their complex offshore discharge requirements. Although container ships are not the best suited for offshore operations, the scarcity of other ship types will dictate their use in the future. It can be assumed that, as more container ships become available, and as breakbulk ships are phased out, container ships will be available more promptly than they are at present.

10.2 RECOMMENDATIONS

- Develop offshore discharge cargo rates meeting required delivery time criteria for size and composition of force to be supported, in order to arrive at specifications for hardware development.

- Examine merchant ship availabilities to determine if and how they can be lowered.

- Establish the MSC reserve fleet with 20 breakbulk ships or ships with similar characteristics.

APPENDIX A
DESCRIPTION OF REACT COMPUTER PROGRAM

REACT* is a computer simulation model used in the study and analysis of shipping operations. The model was designed to allow an analysis of a wide spectrum of shipping conditions and situations and to recognize differences in cargo types.

REACT considers a system of ports to which cargo is to be delivered and specified origin ports where cargo is available. The general problem is to transport cargo from the origin ports to the required destinations using the ship inventory that is available. REACT simulates shipping operations in which the origin ports, destinations, and ship inventory are defined in the input data.

The output statistics of the model are designed to assess the performance of the simulated shipping operations. The output contains summary information for each port in the system, including its use by the ships in the inventory and the amounts of cargo that entered or left the port. From this information the adequacy of the berthing facilities at a specific port, or the ability of the shipping inventory to respond to the hypothesized cargo movement required in the scenario can be determined. Further analysis may indicate the desirability of ships with specific physical characteristics or the need for specialized berthing facilities at particular ports. The output also indicates the specific ships that were used and the number of trips made by each ship.

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* REACT computer user's manual is in preparation.

APPENDIX B
GRAPHS OF COMPUTER RUNS

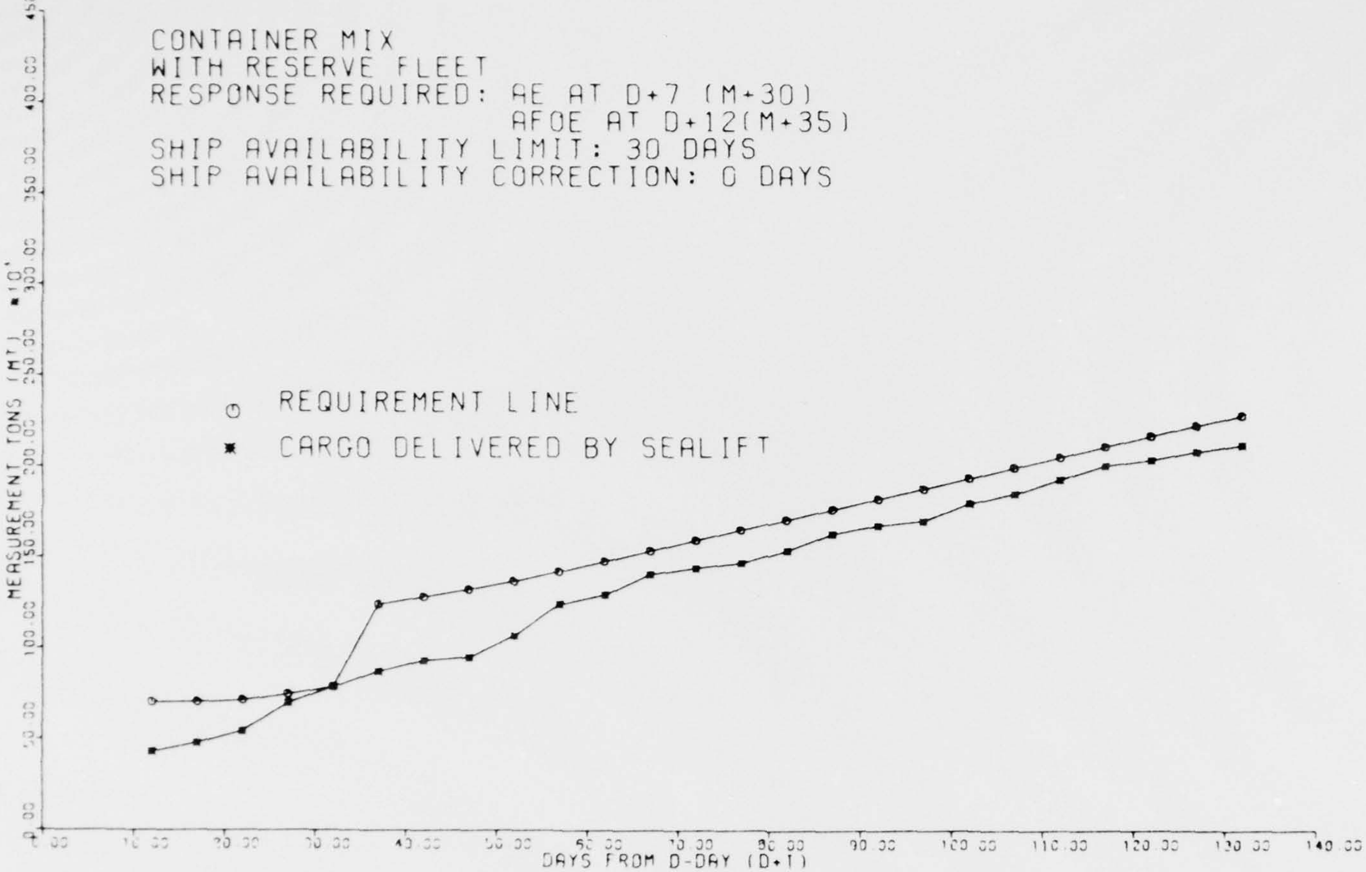

FIGURE 2 -CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE CT1

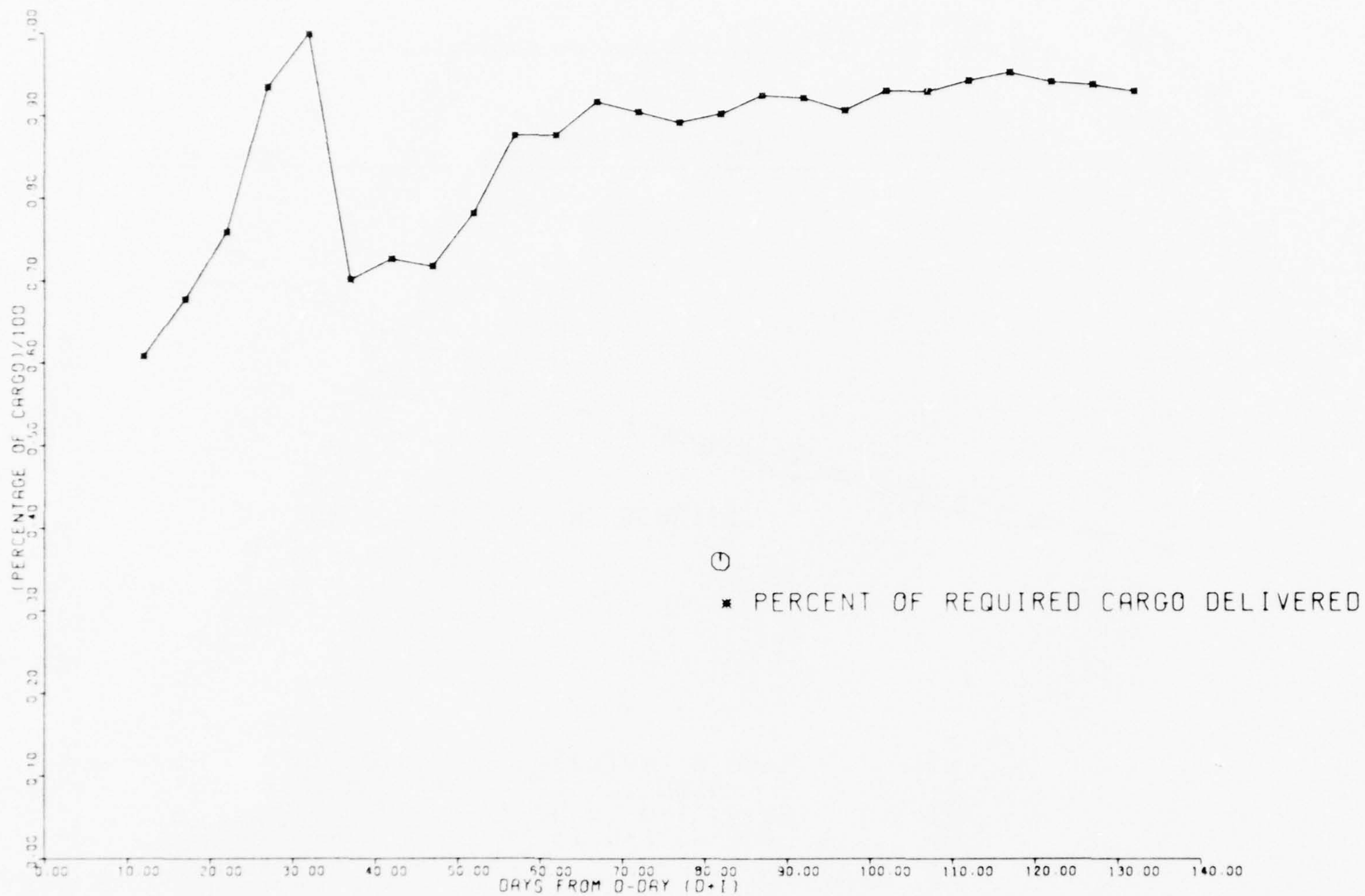

FIGURE 3 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE CT1

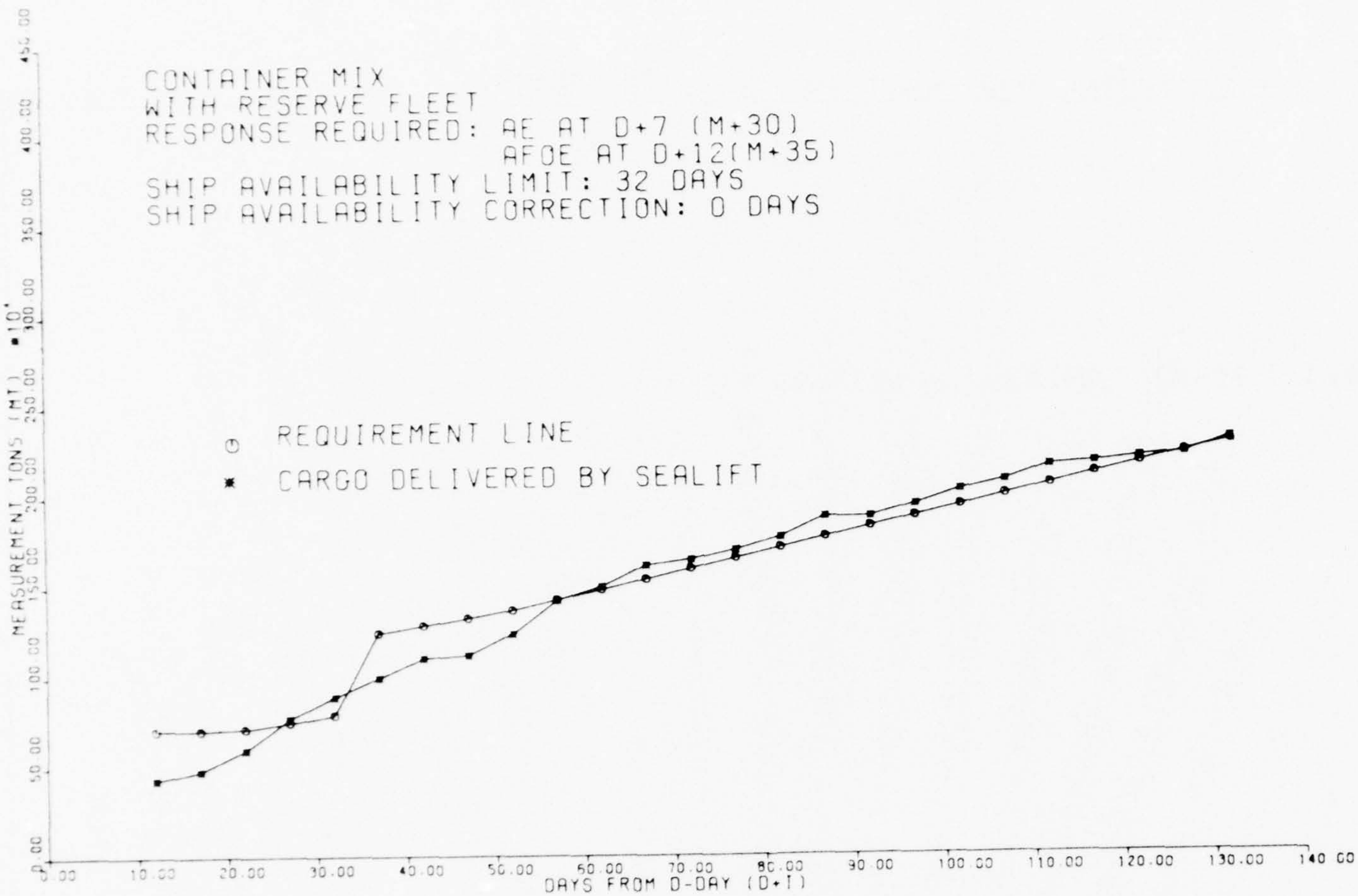

FIGURE 4 -CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE CT2

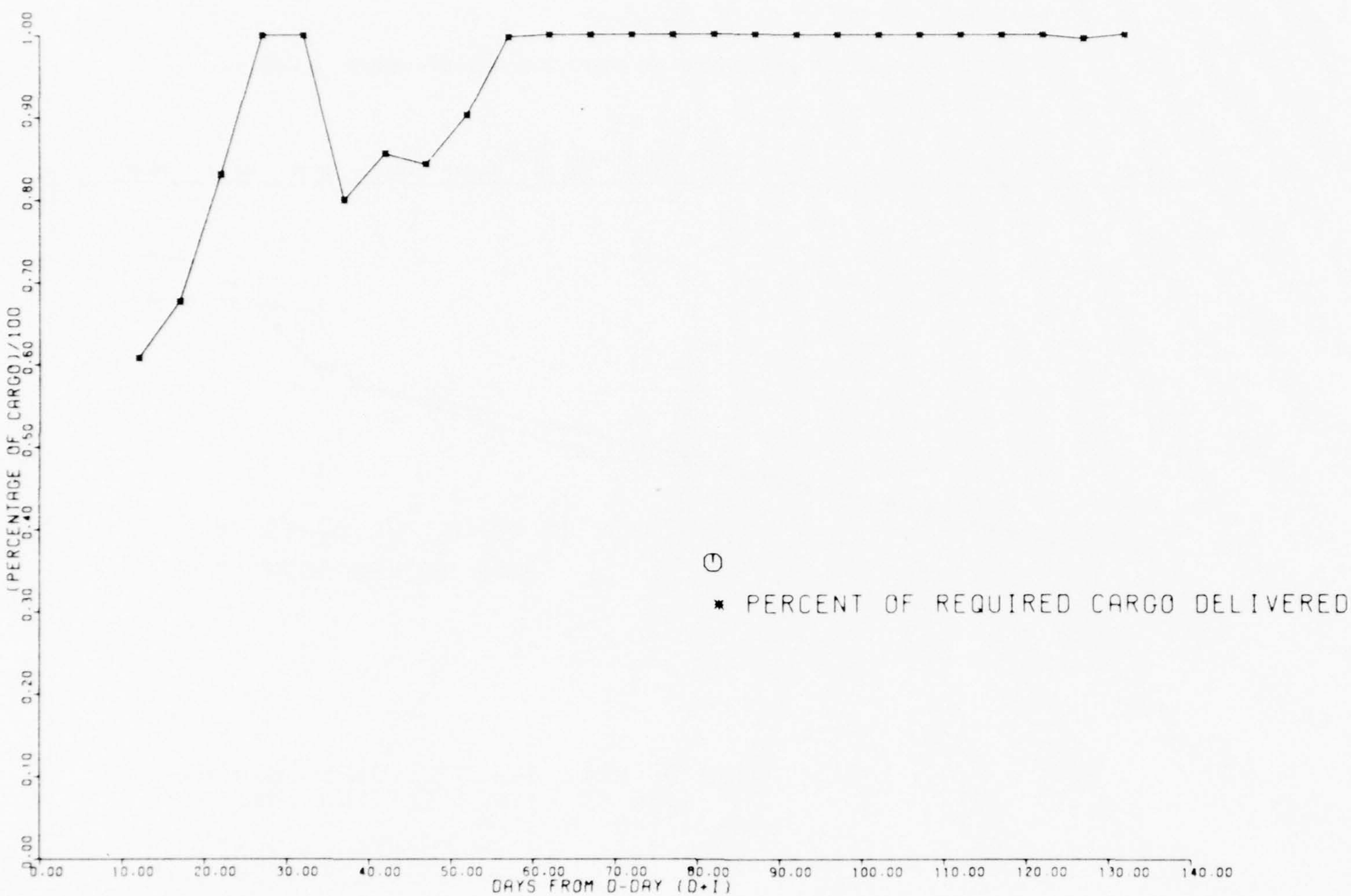

FIGURE 5 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE CT2

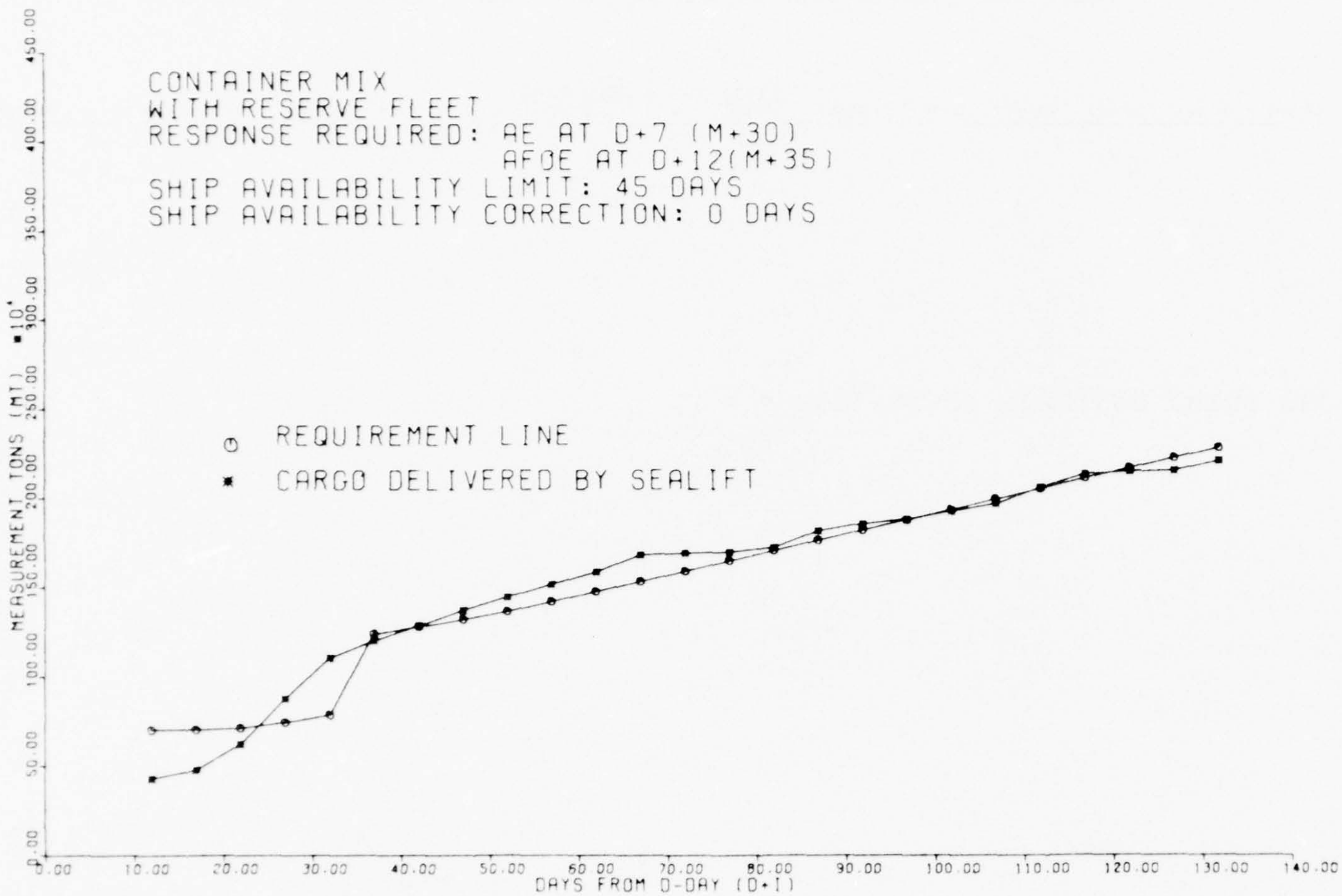

FIGURE 6 -CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE CT3

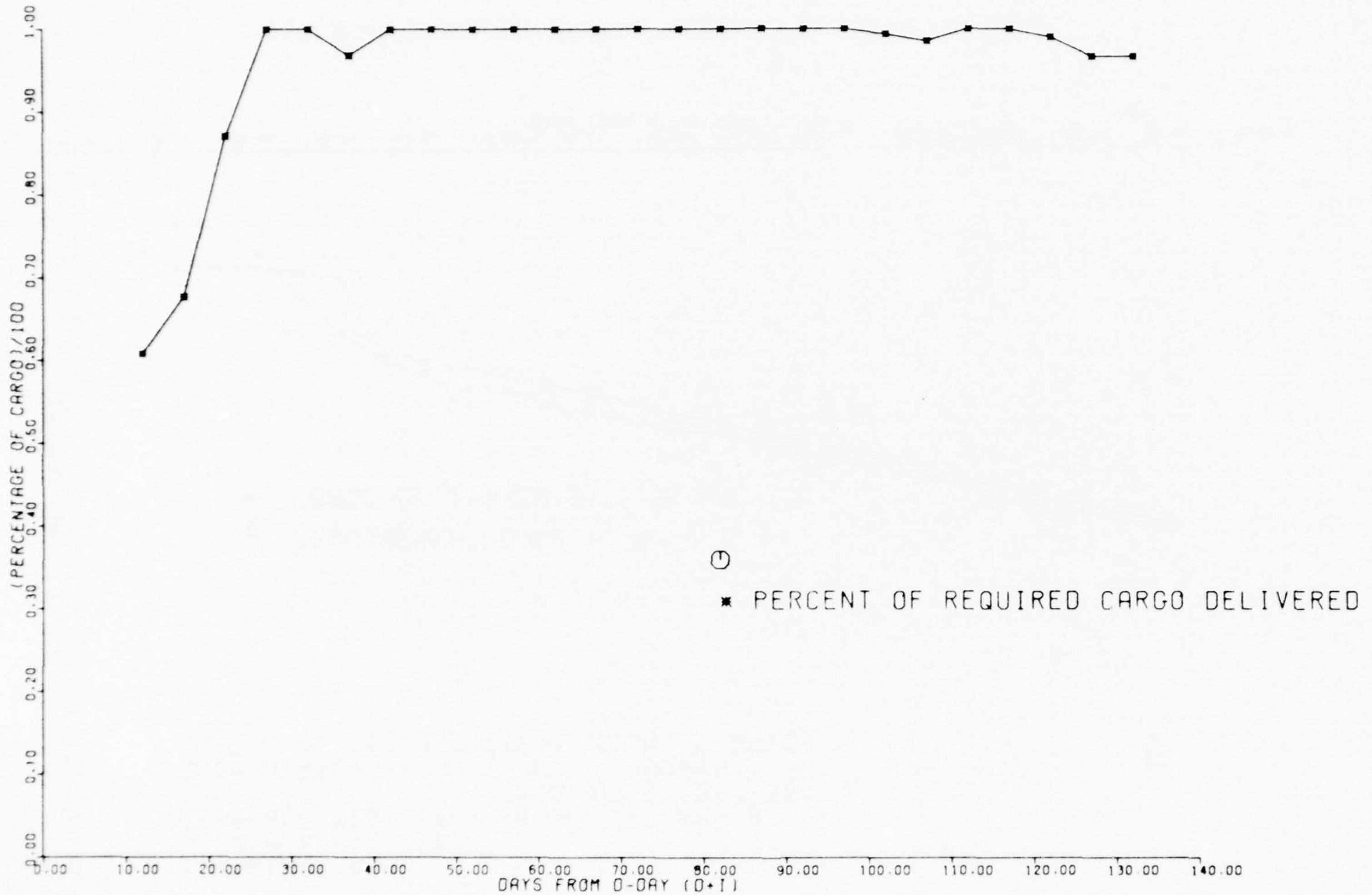

FIGURE 7 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE CT3

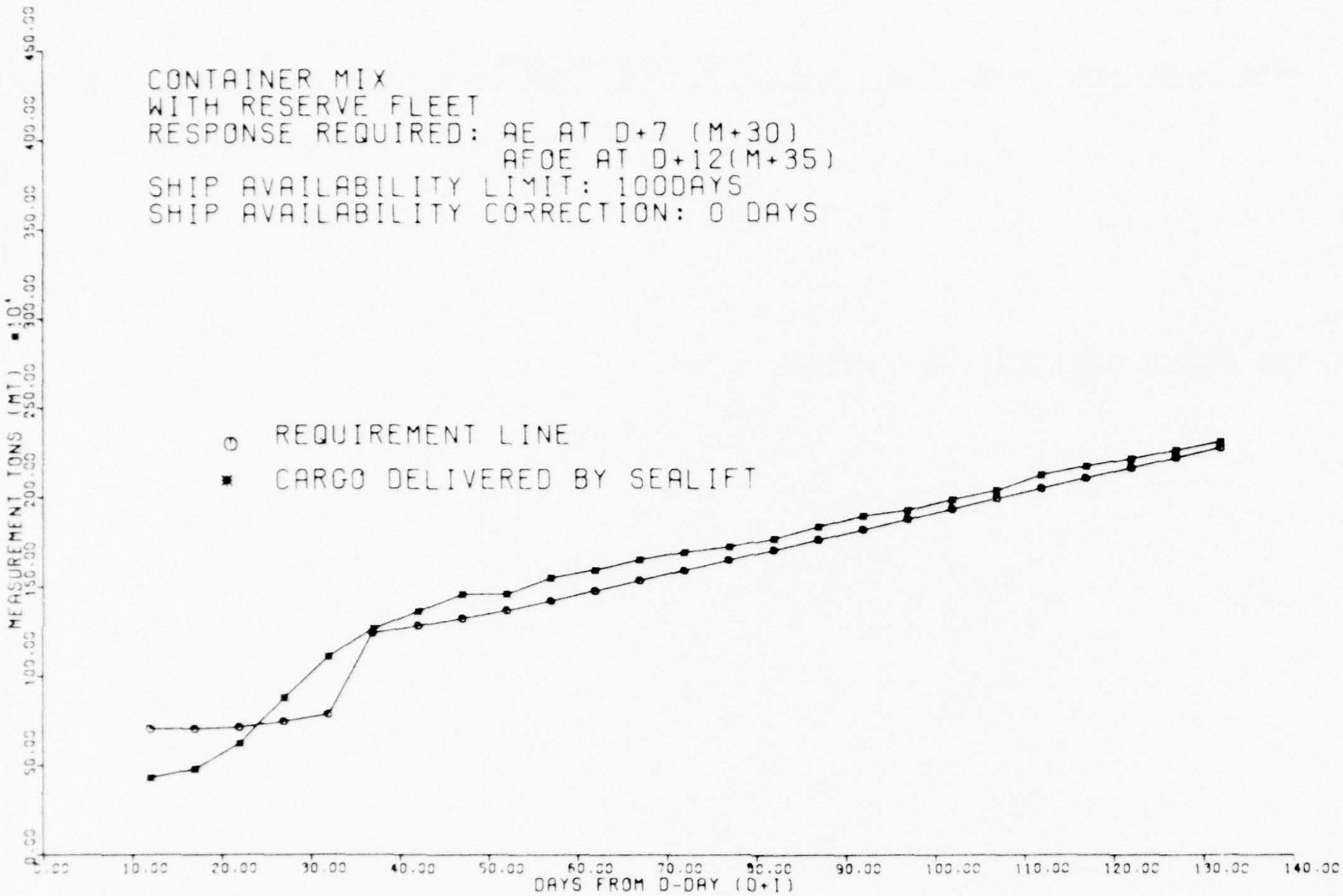

FIGURE 8 -CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE CT4

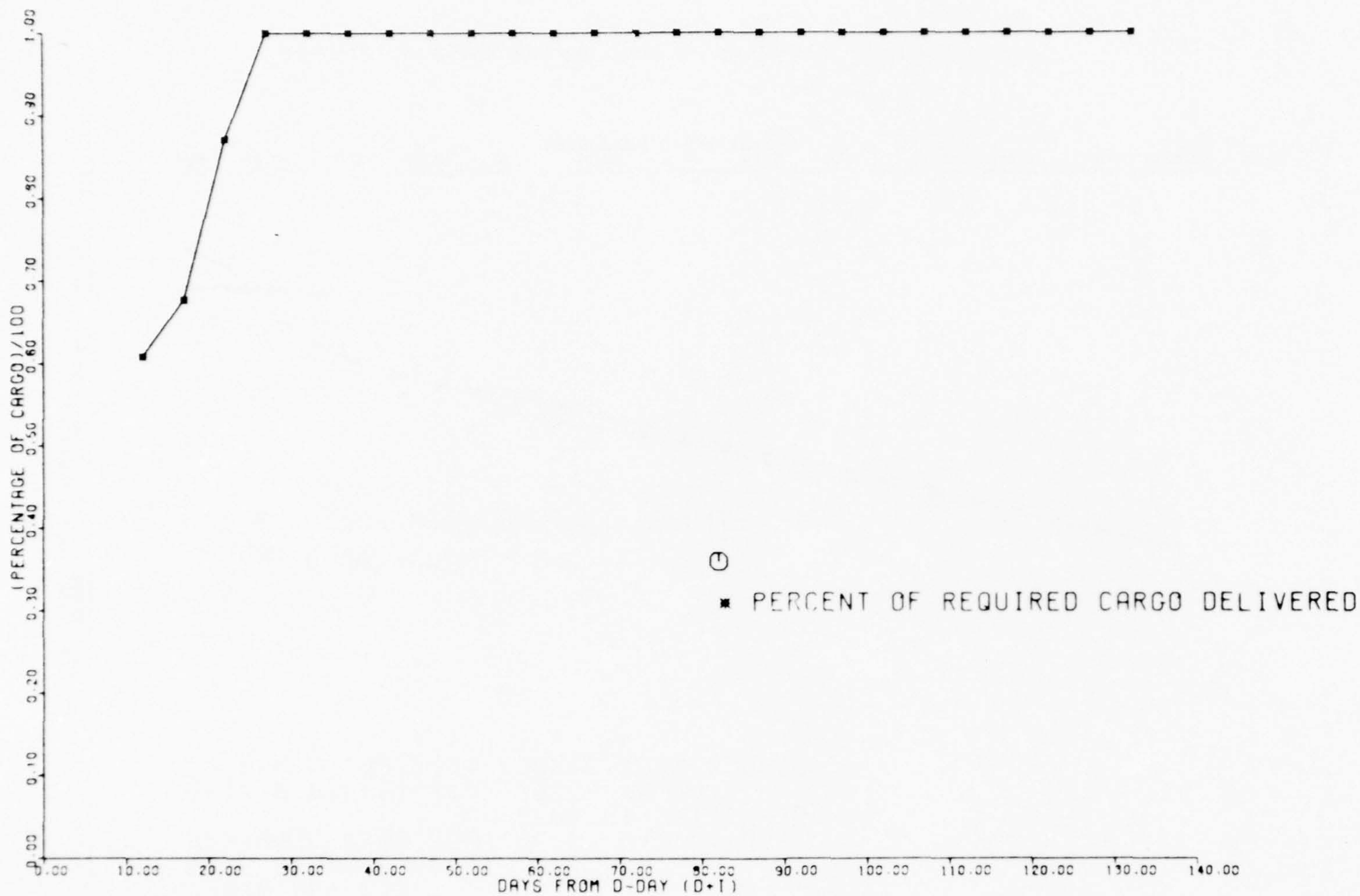

FIGURE 9 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE CT4

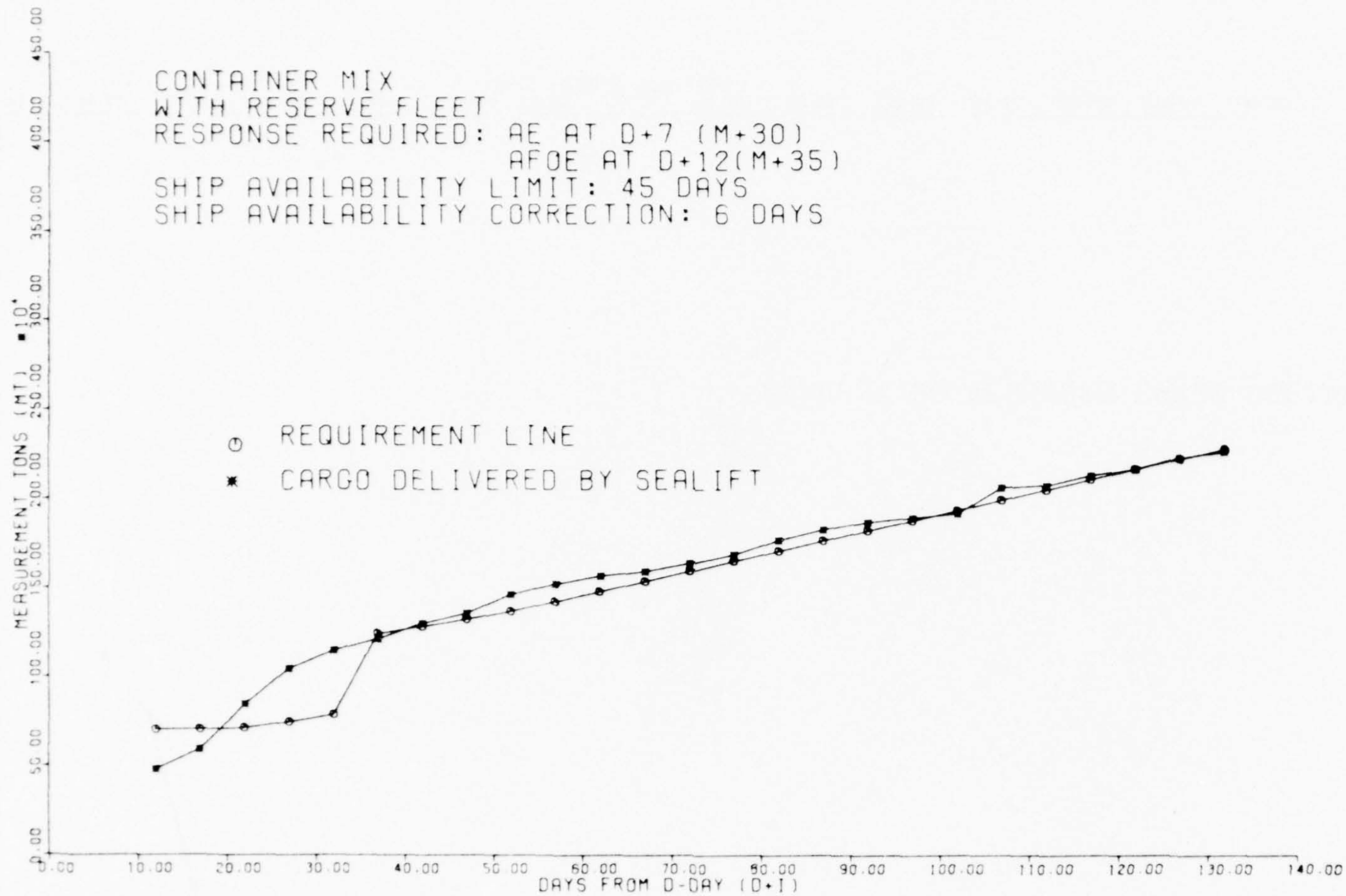

FIGURE 10-CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE CT5

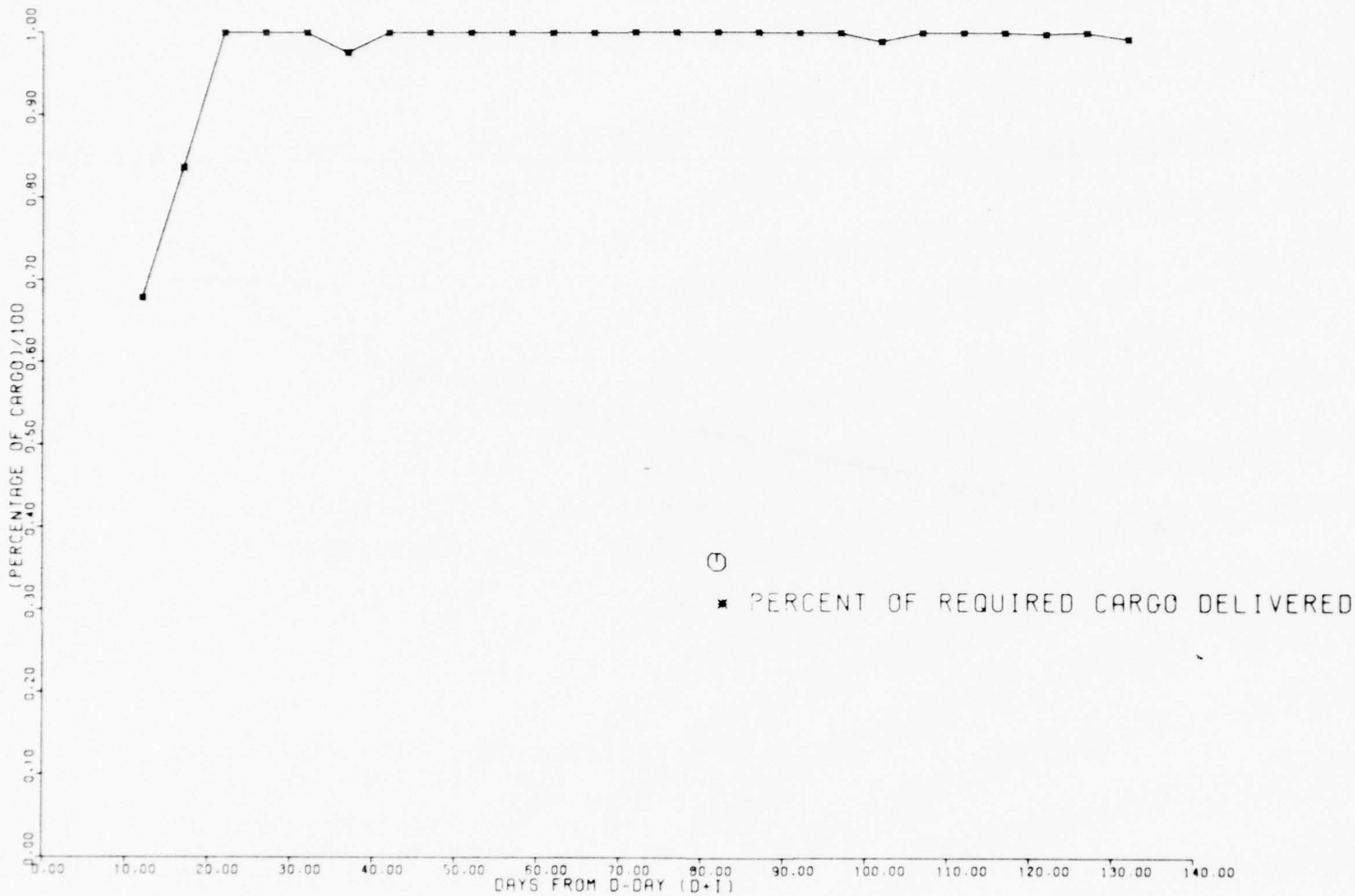

FIGURE II-PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE CTS

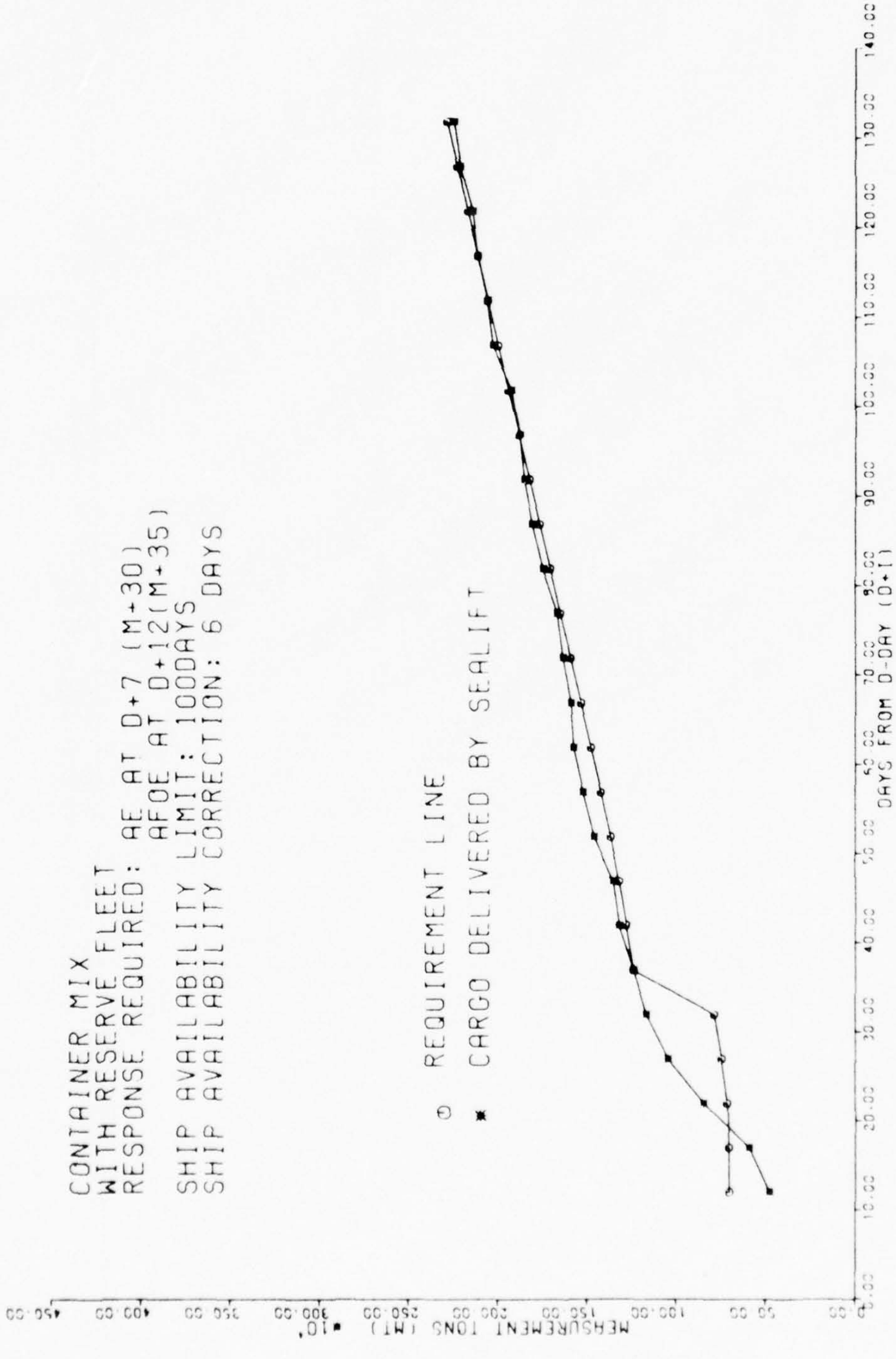

FIGURE 12-CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE CT6

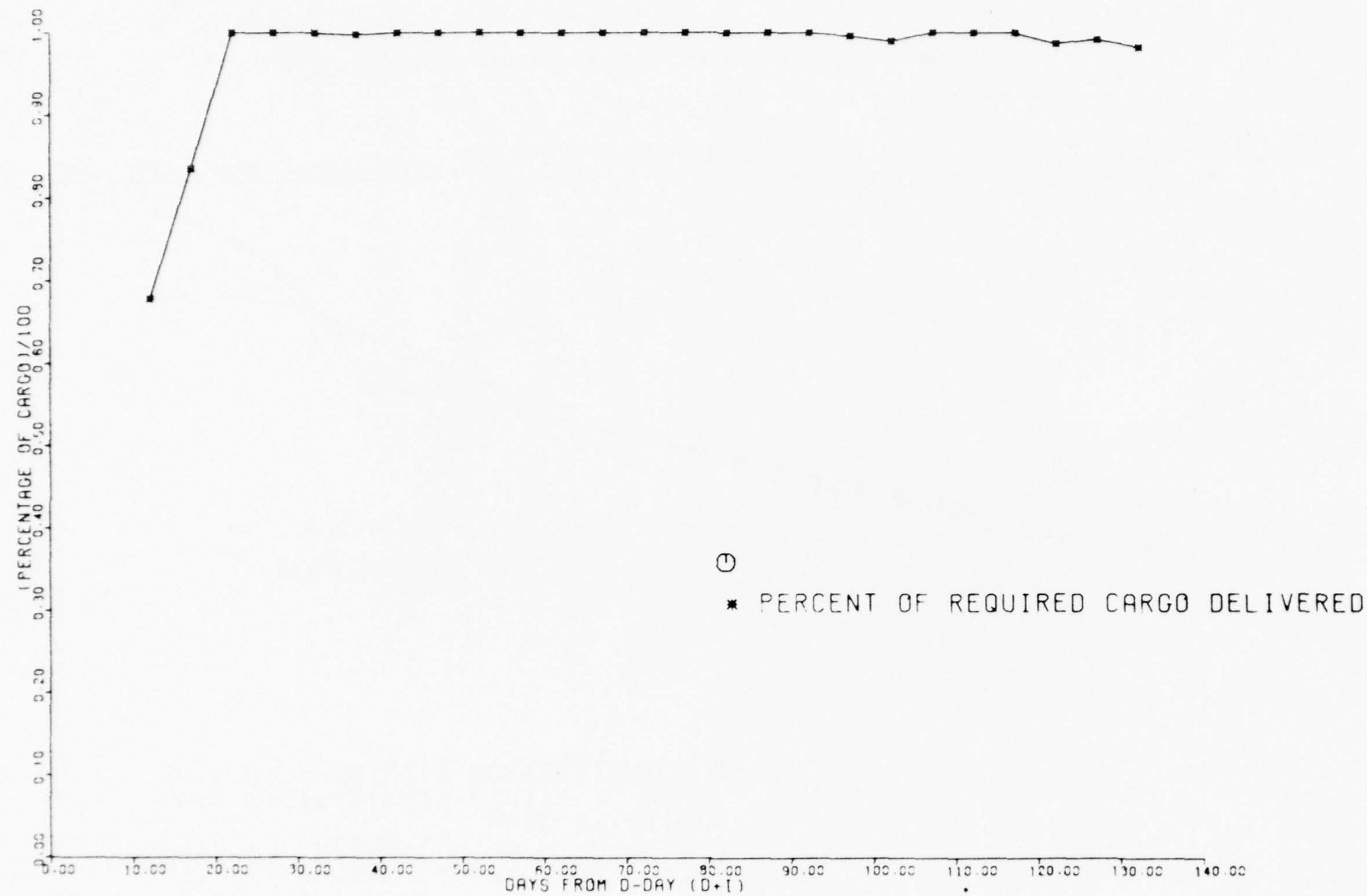

FIGURE 13 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE CT6

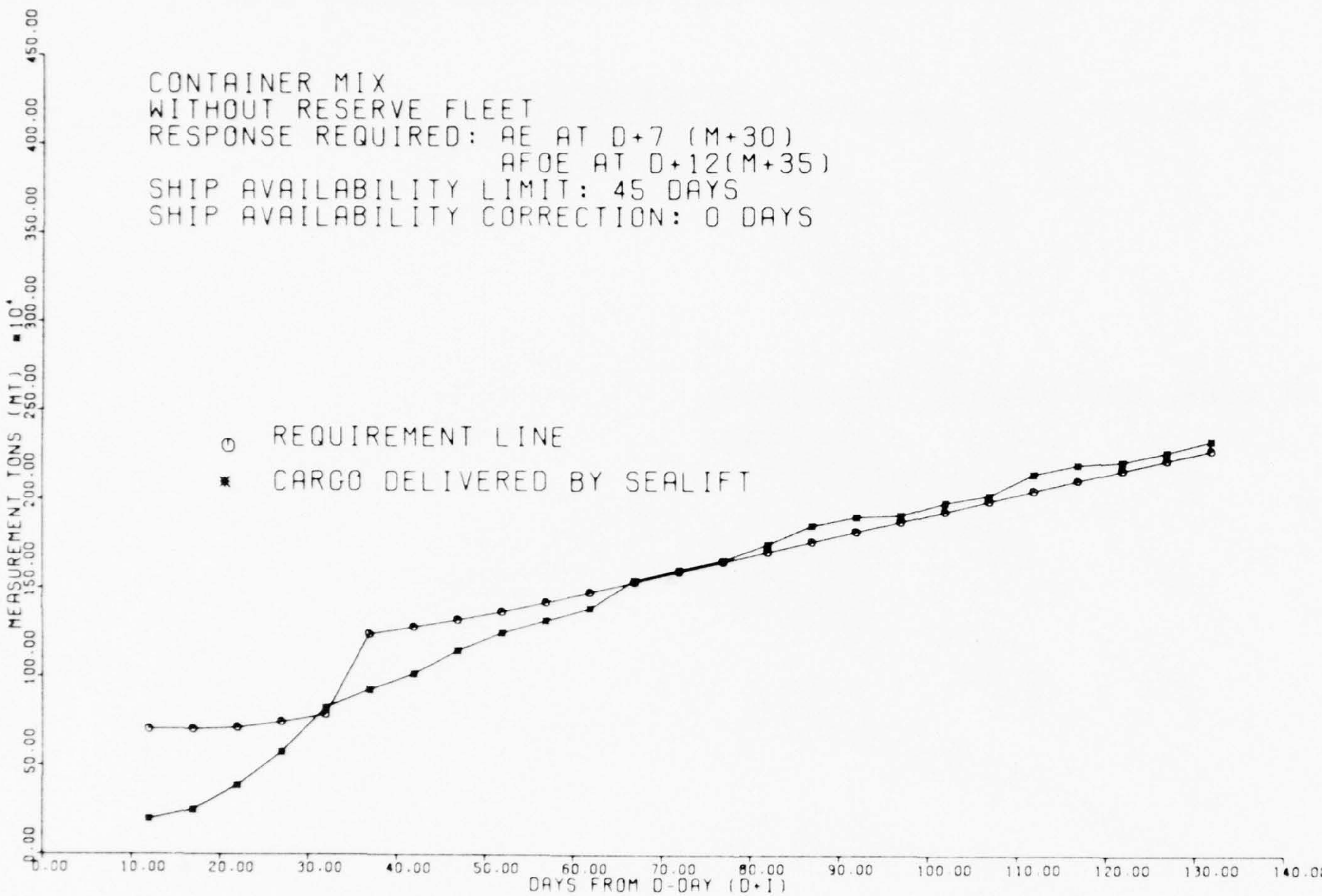

FIGURE 14 -CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE CT7

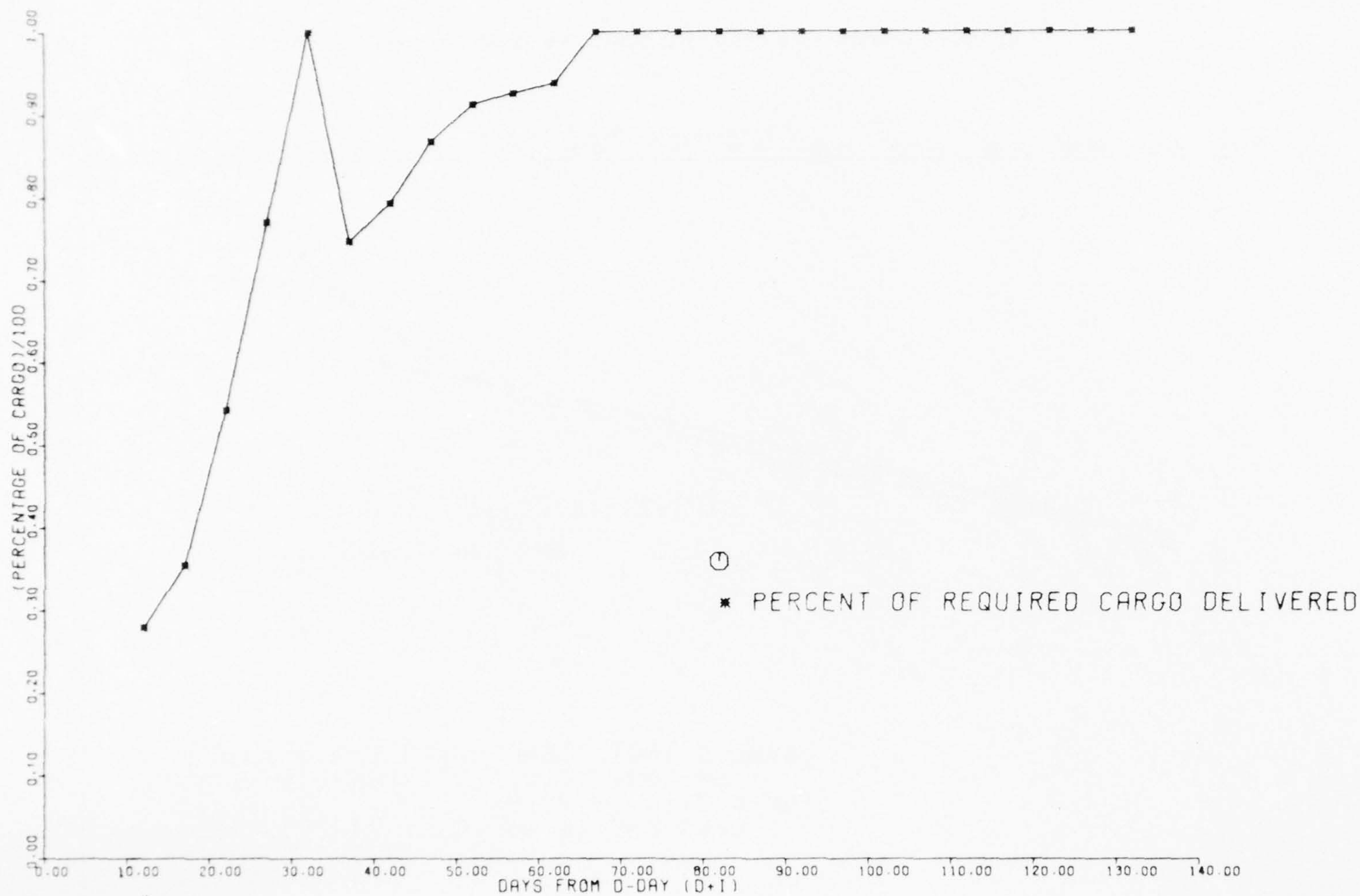

FIGURE 15 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE CT7

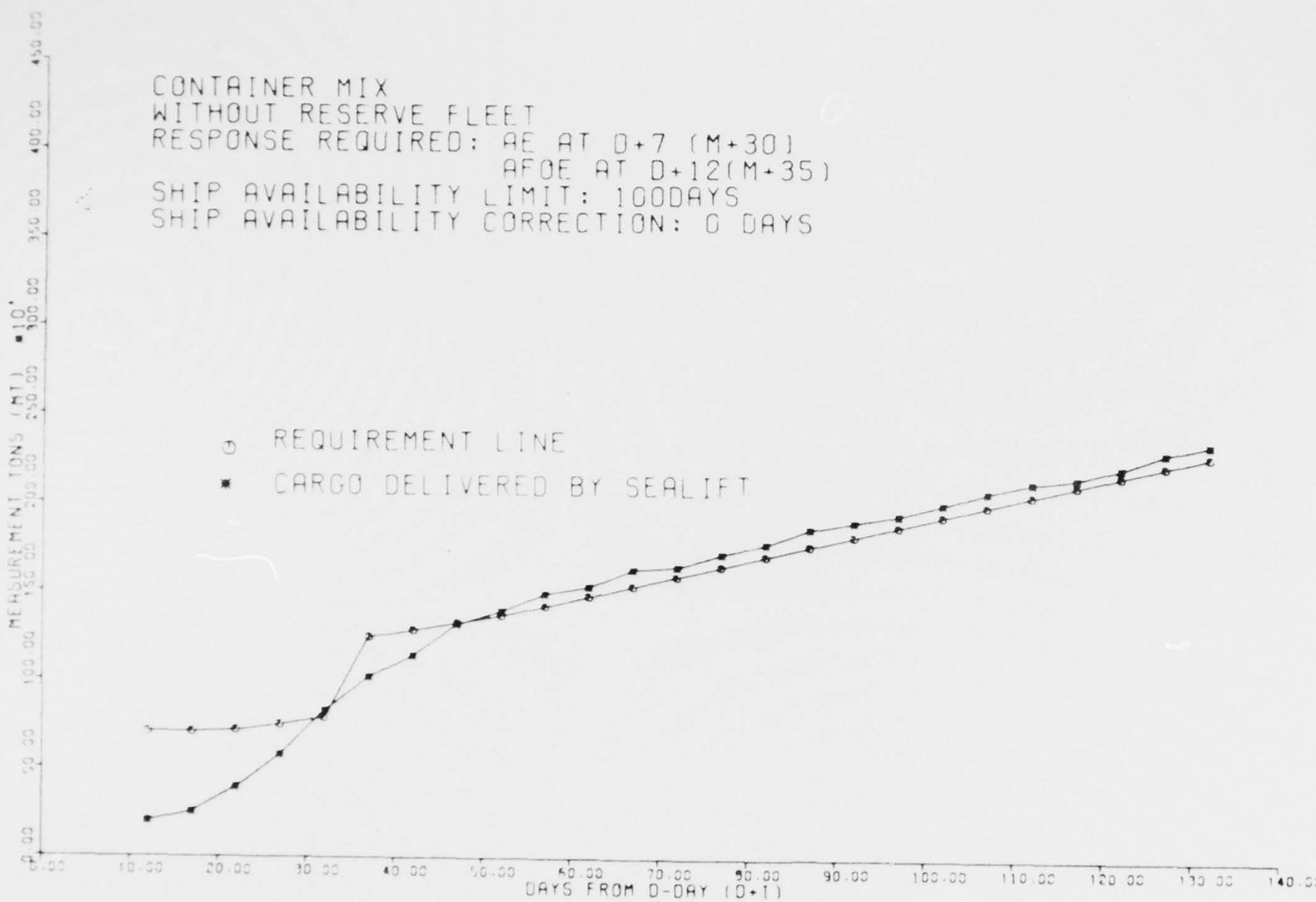

FIGURE 16 -CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE CT8

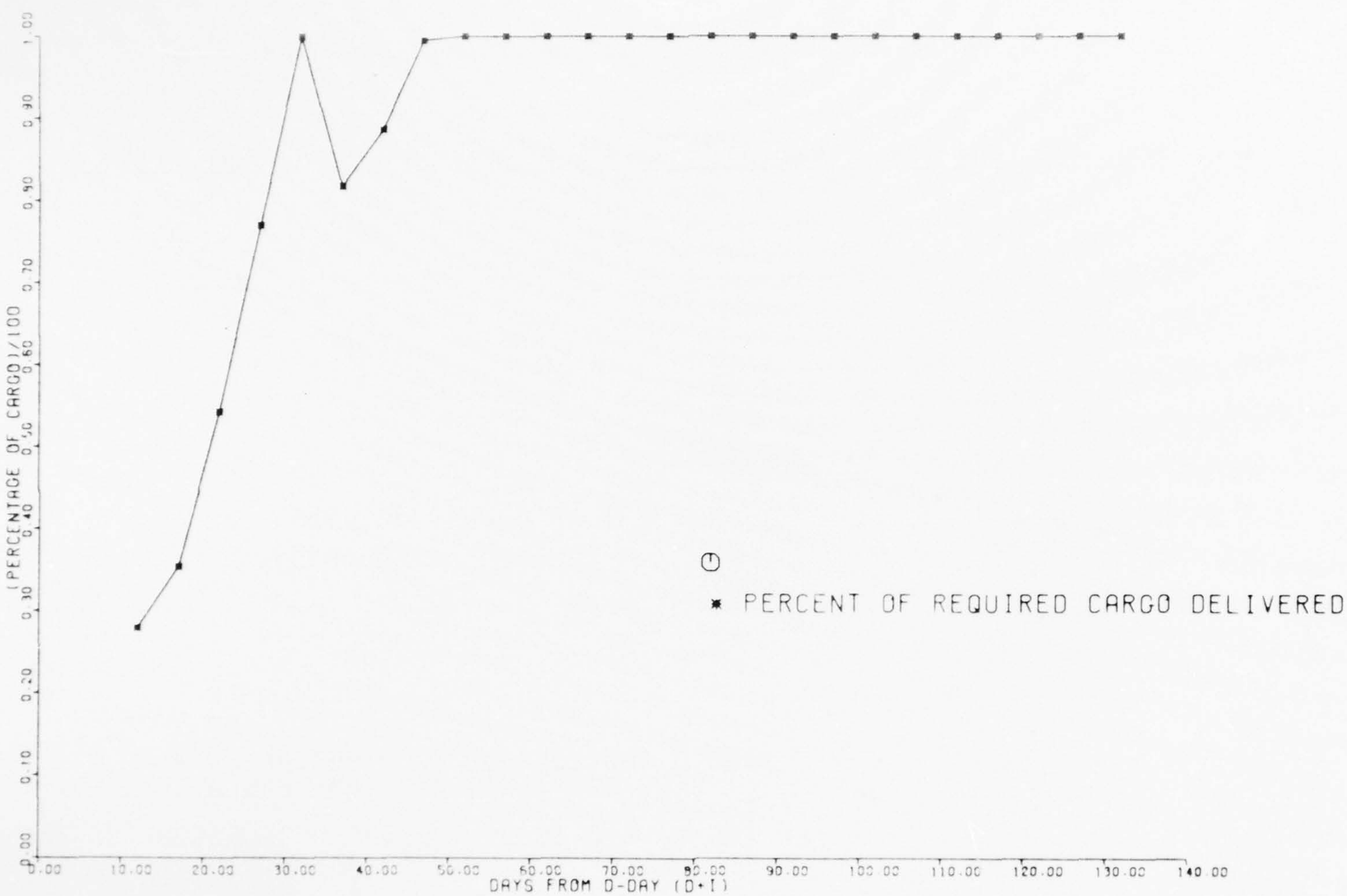

FIGURE 17 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE CT8

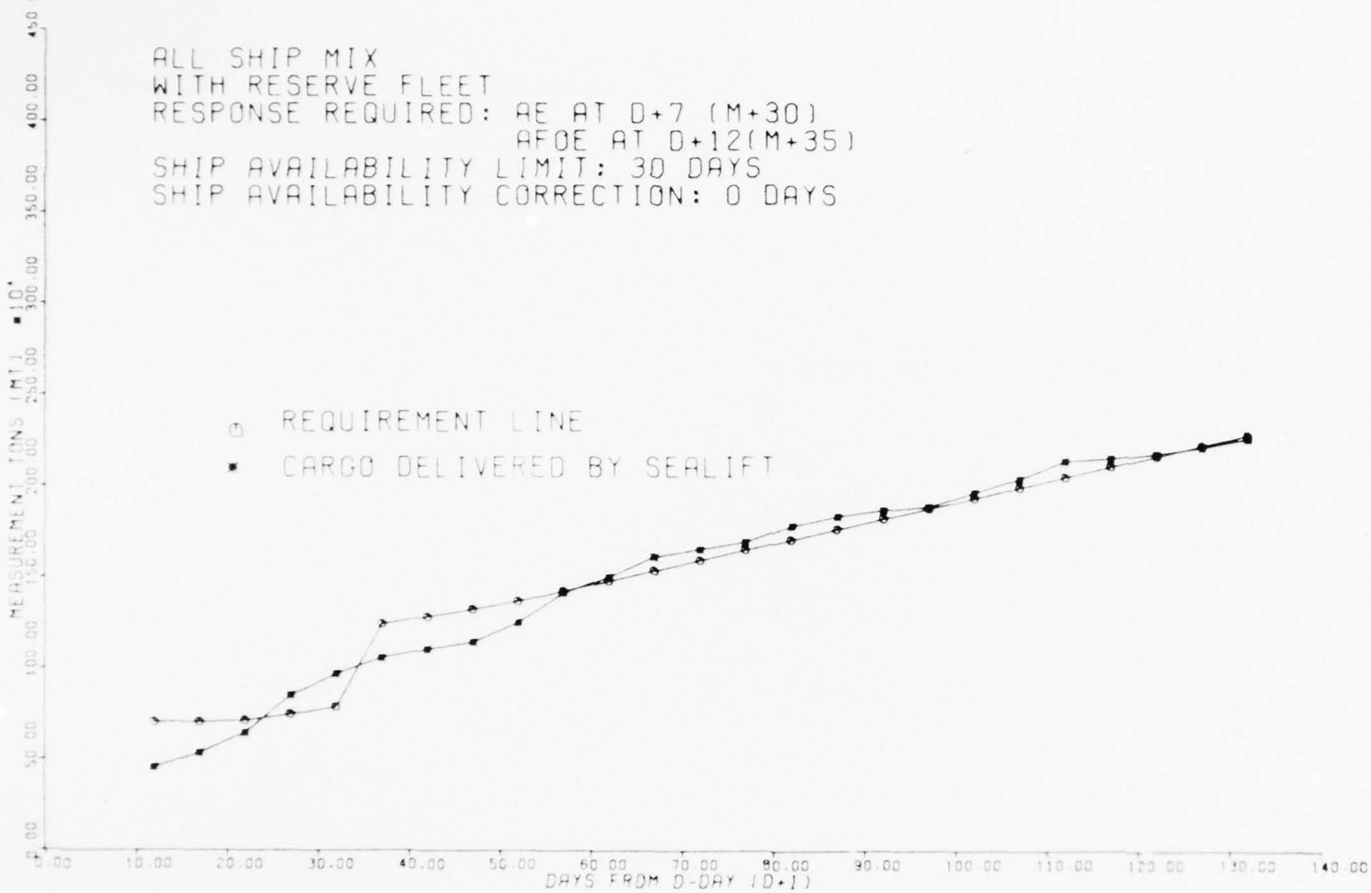

FIGURE 18 -CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE AL1

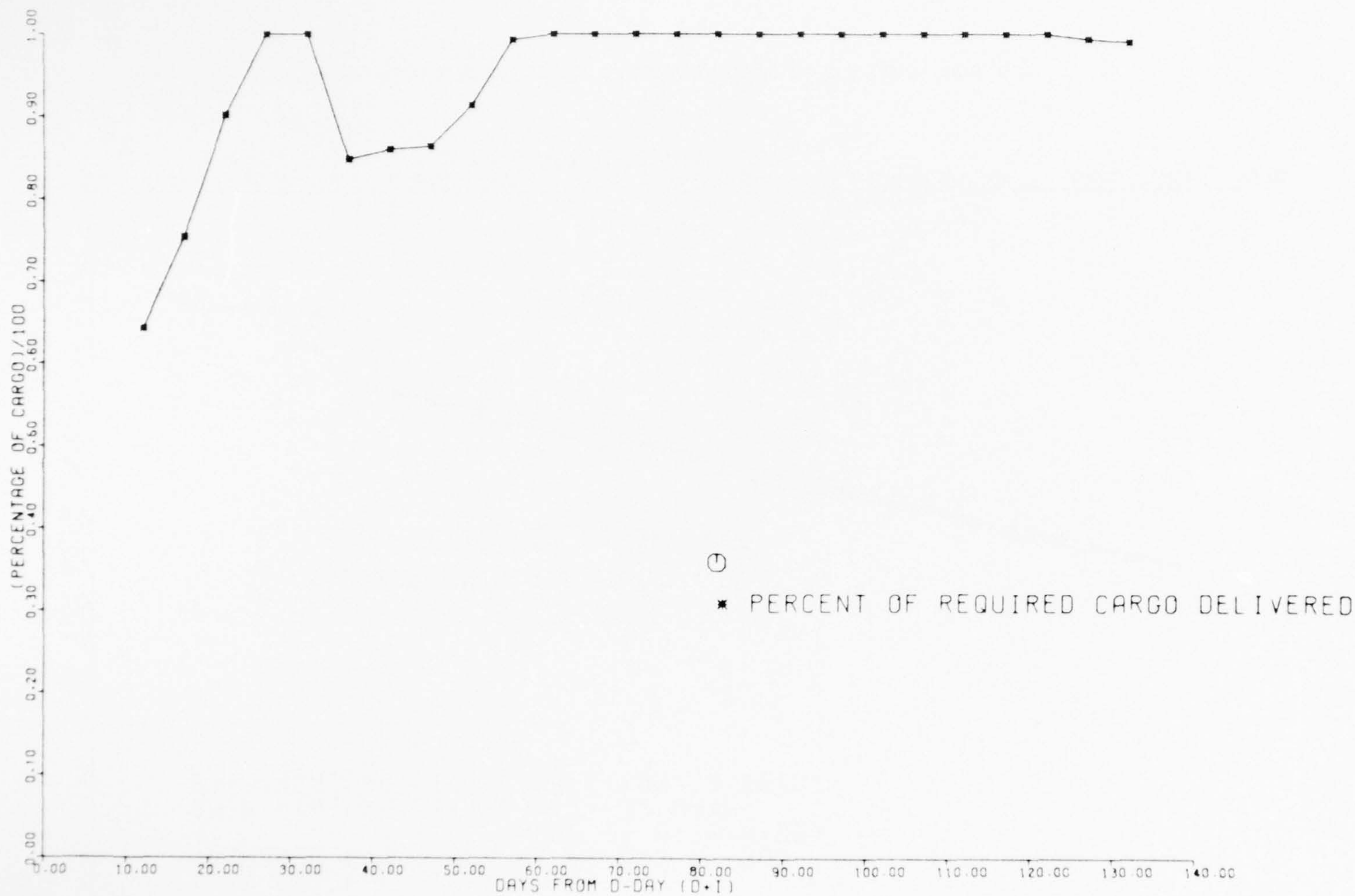

FIGURE 19 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE AL1

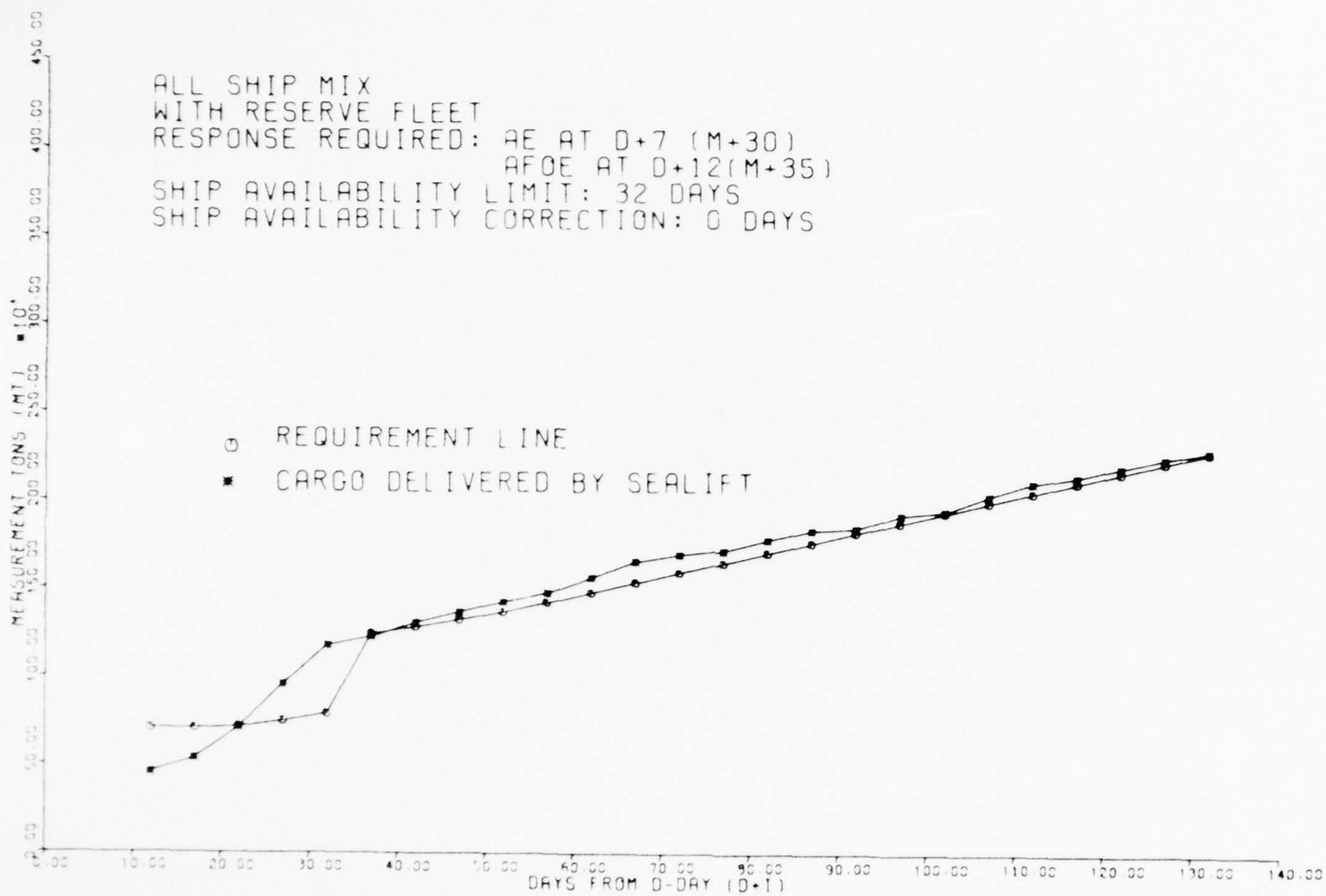

FIGURE 20 -CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE AL2

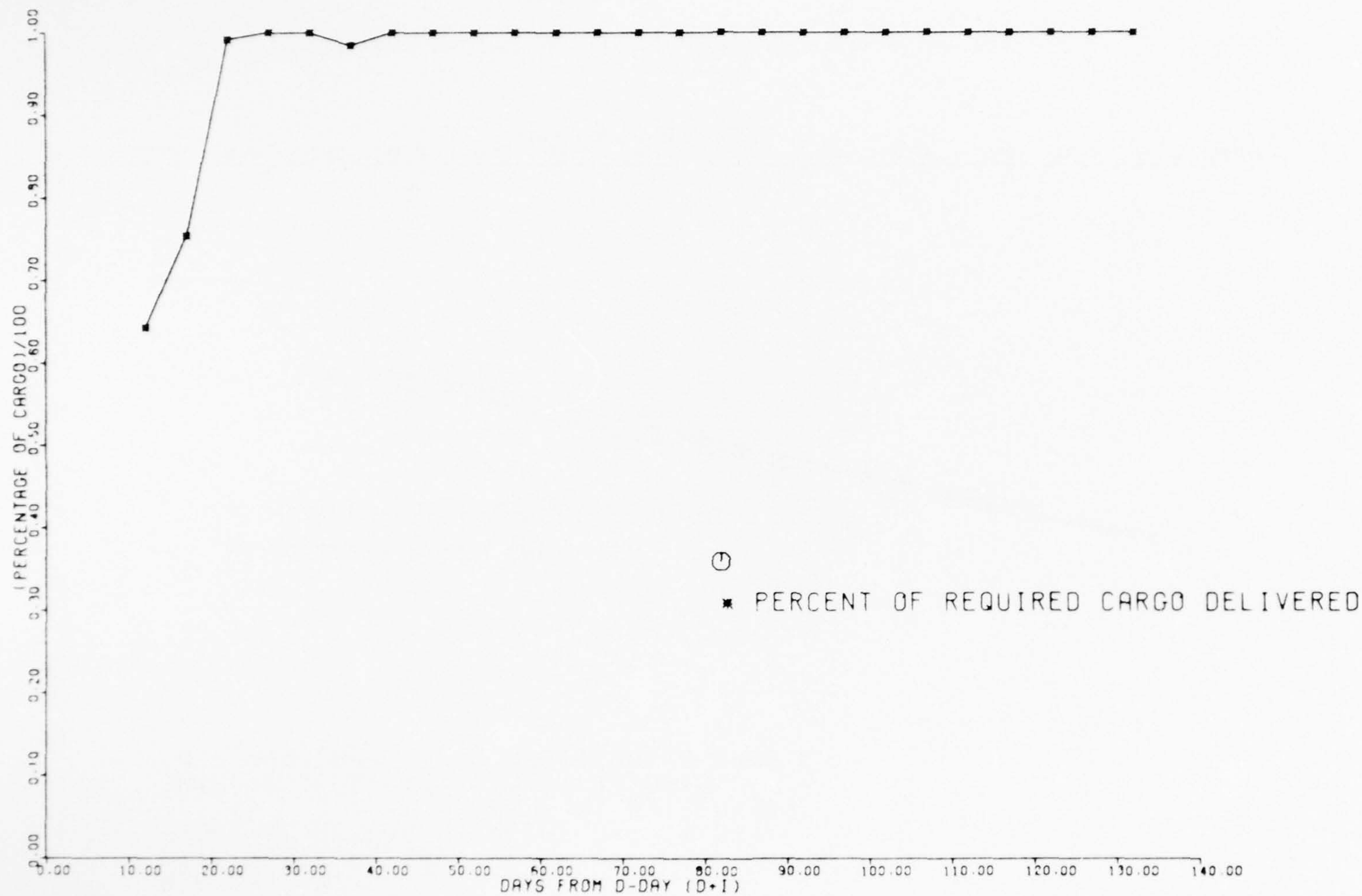

FIGURE 21 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE AL2

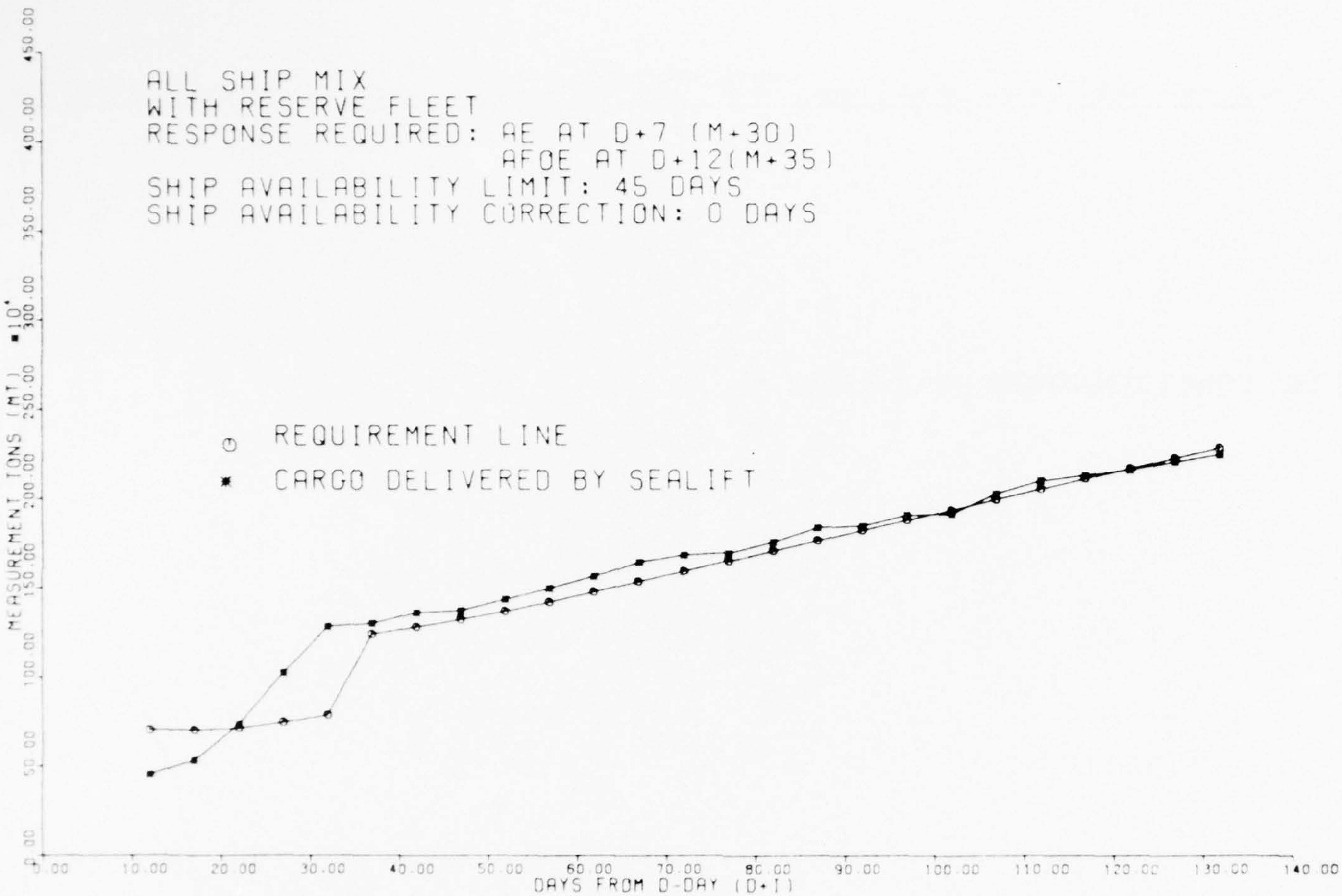

FIGURE 22 - CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE AL3

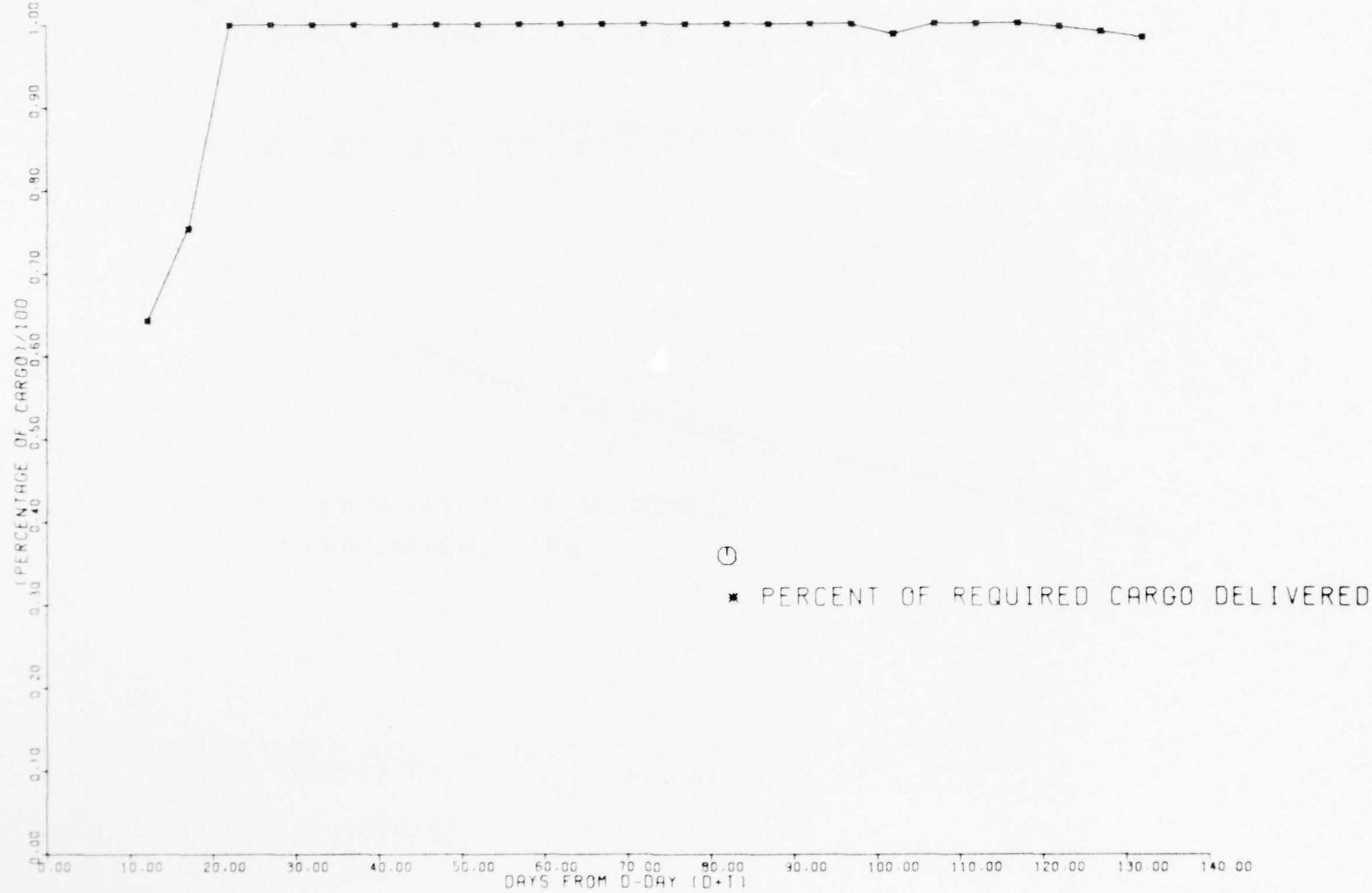

FIGURE 23 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE AL3

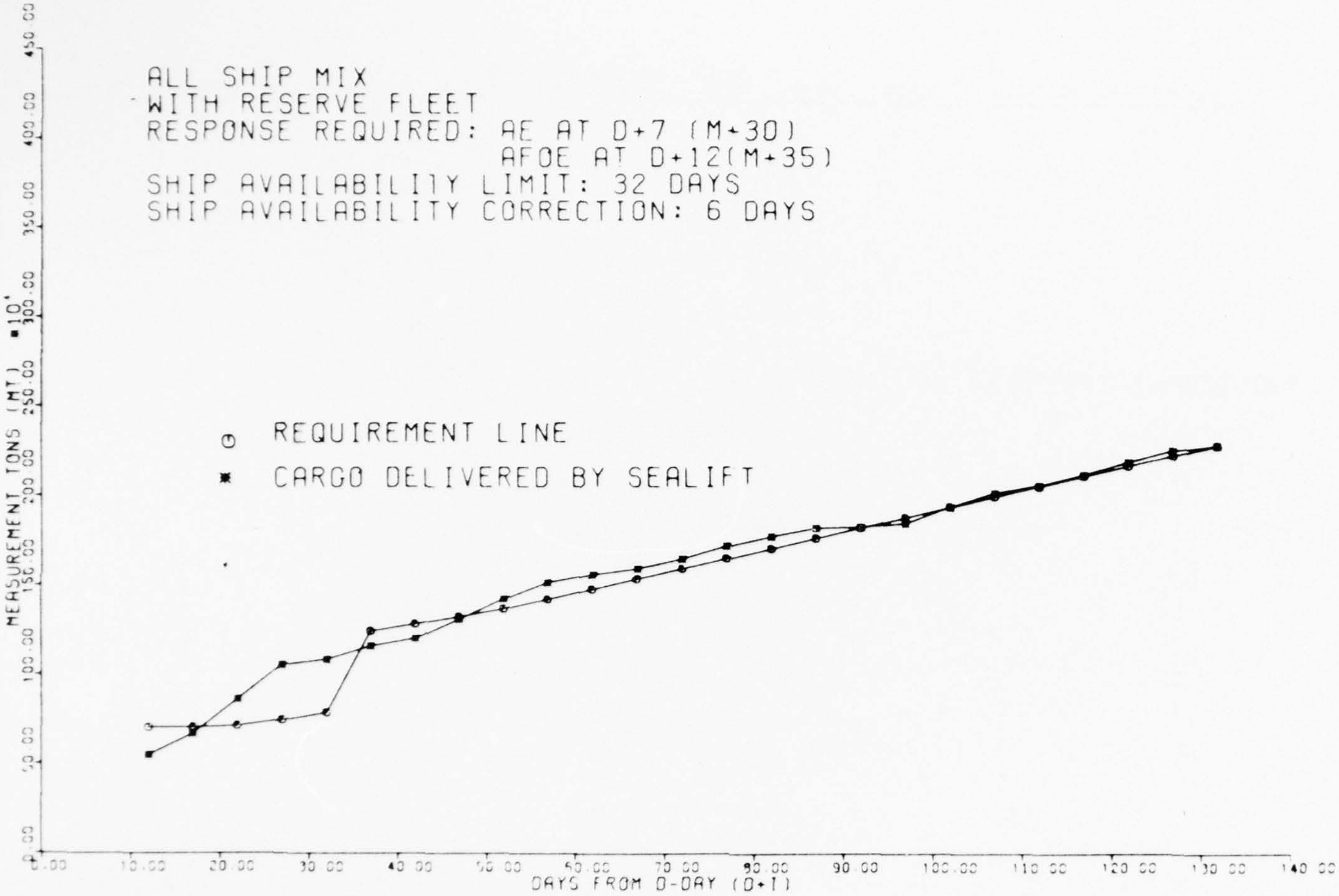

FIGURE 24 - CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE AL4

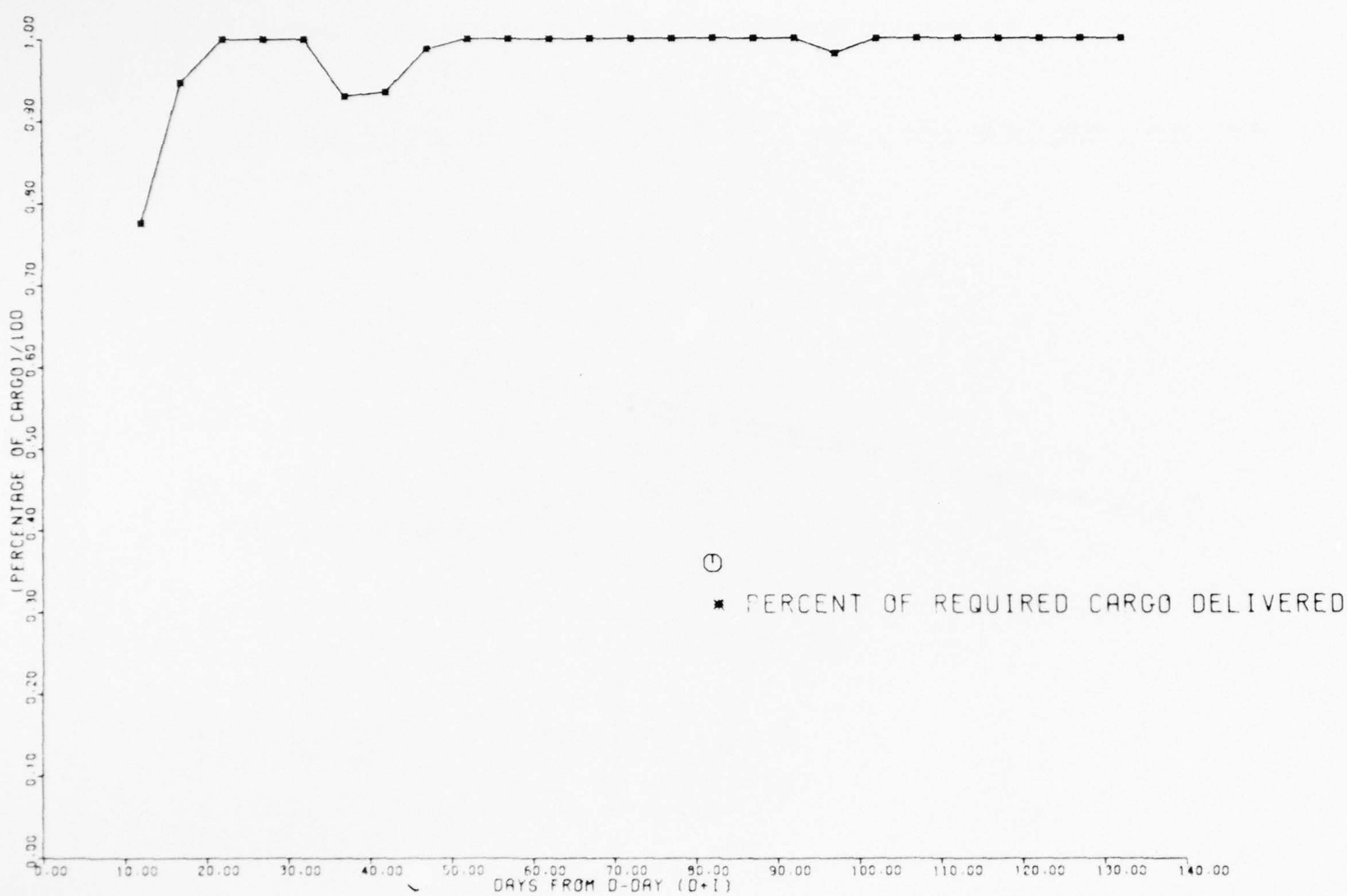

FIGURE 25 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE AL4

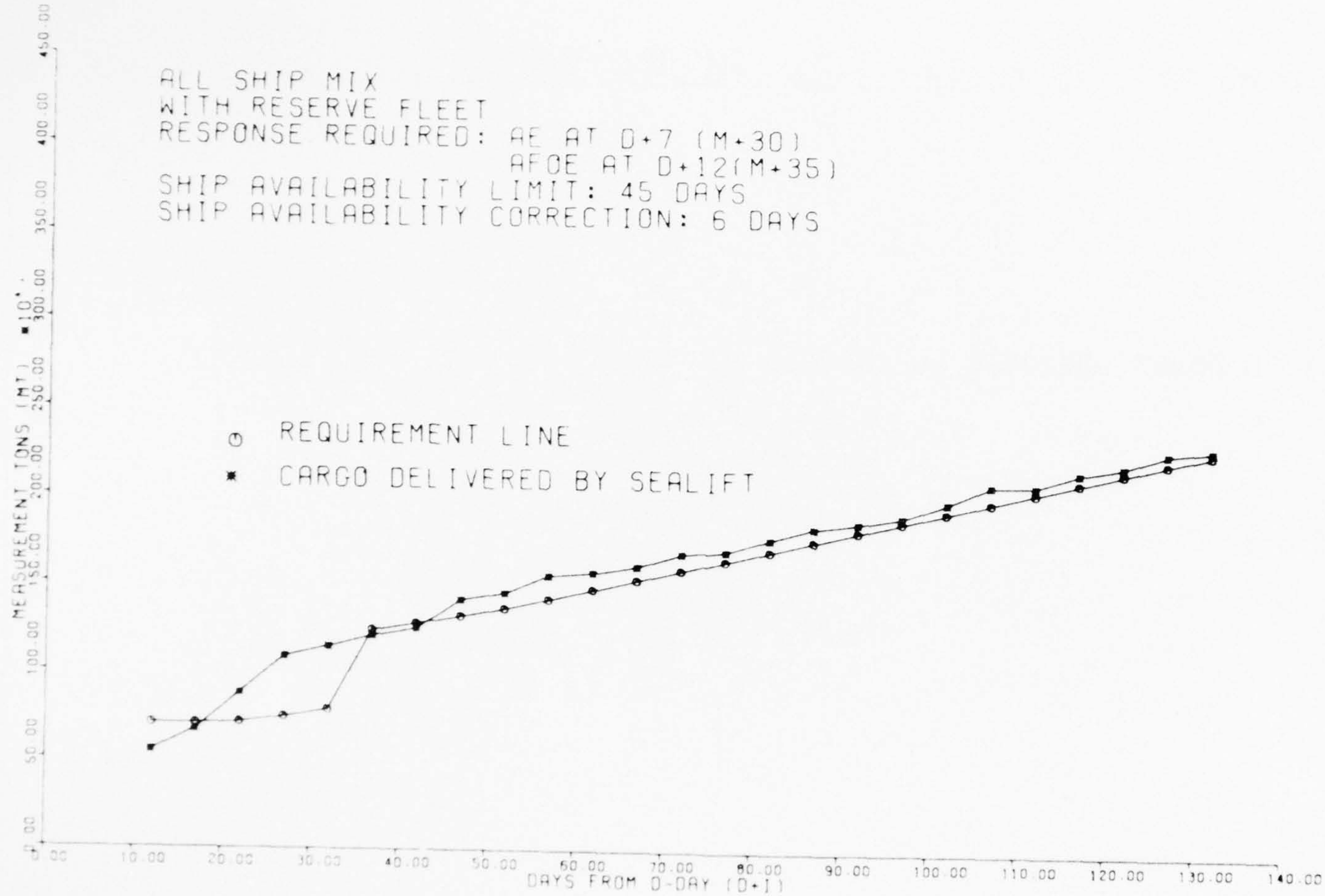

FIGURE 26 - CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE AL5

FIGURE 27 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE AL5

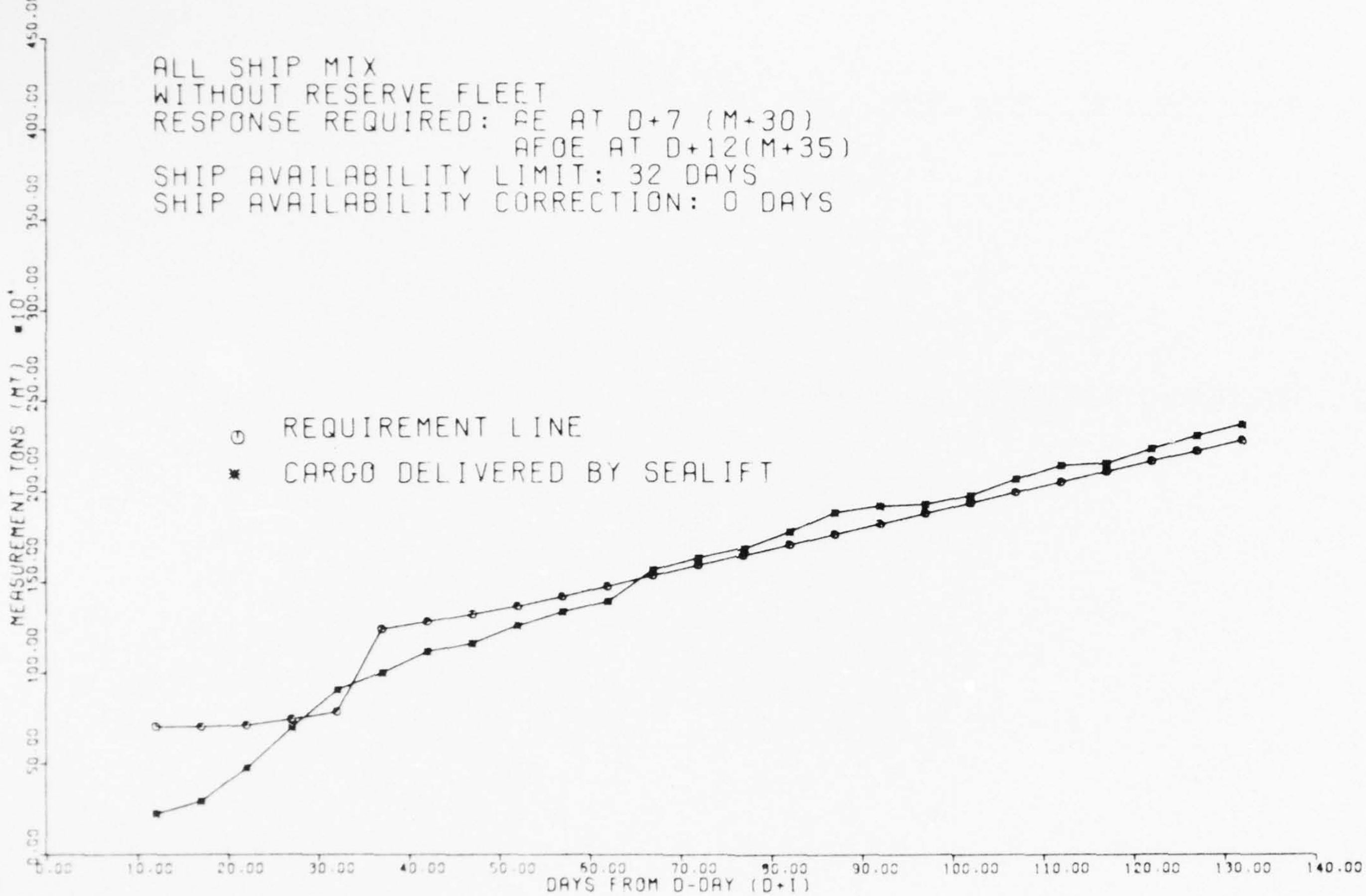

FIGURE 28 -CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE AL6

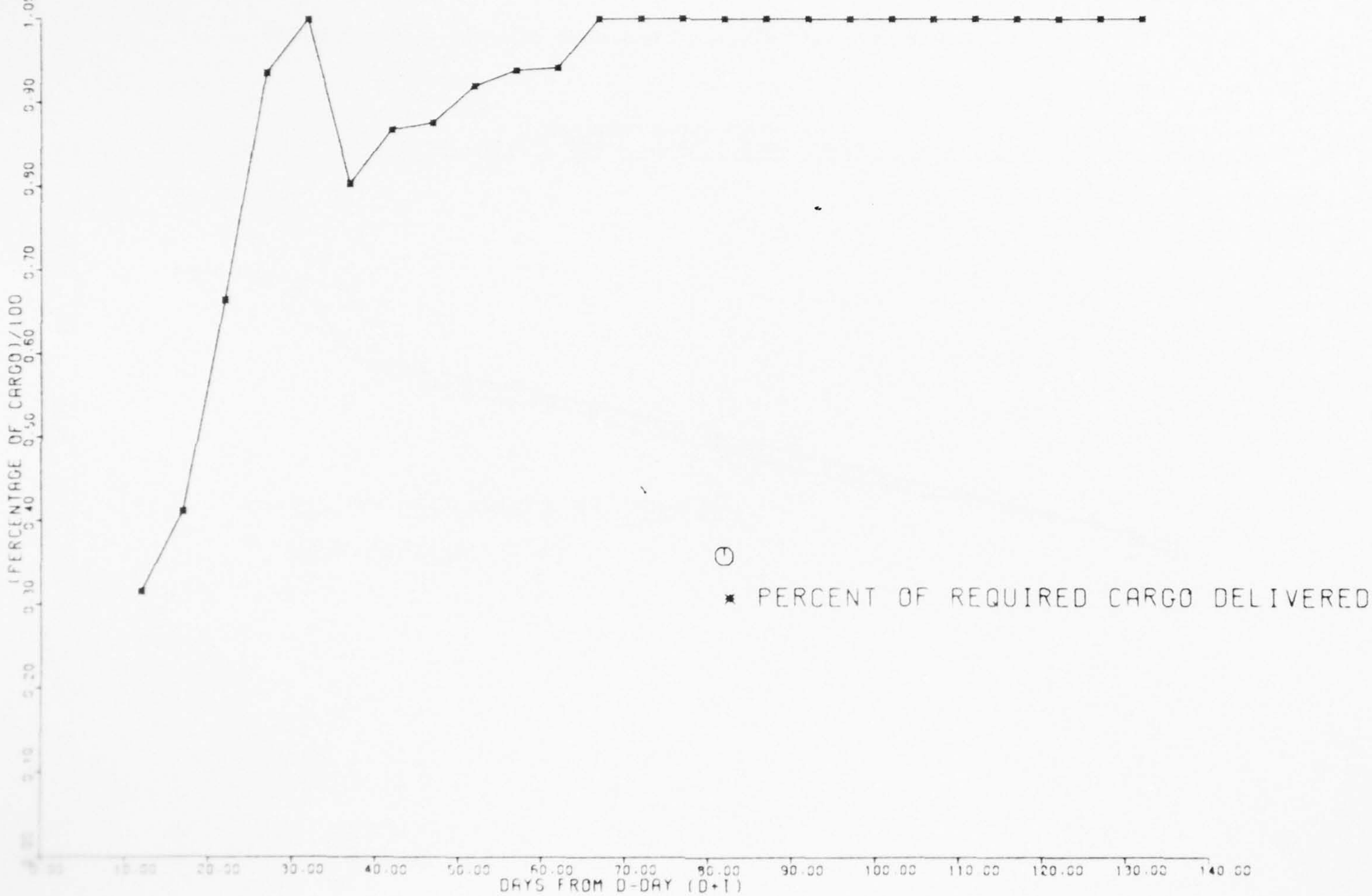

FIGURE 29 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE AL6

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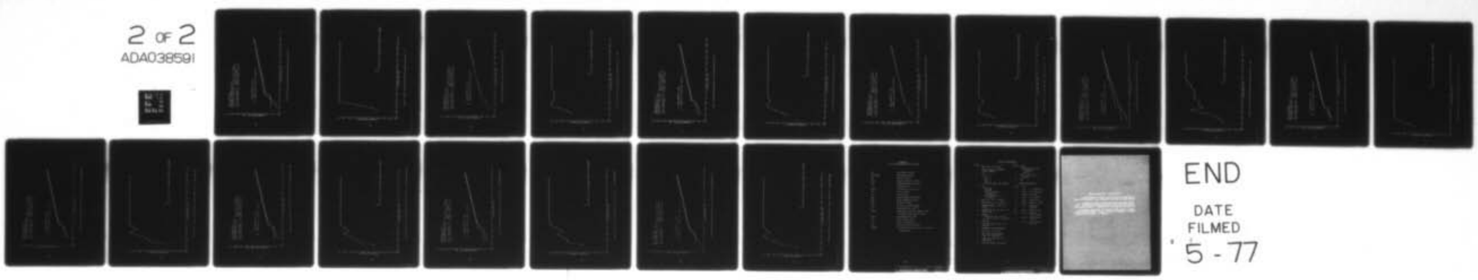

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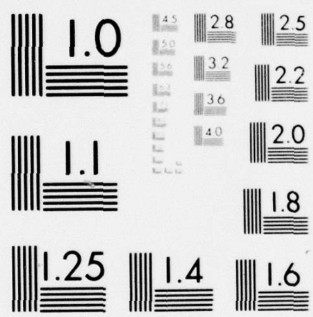

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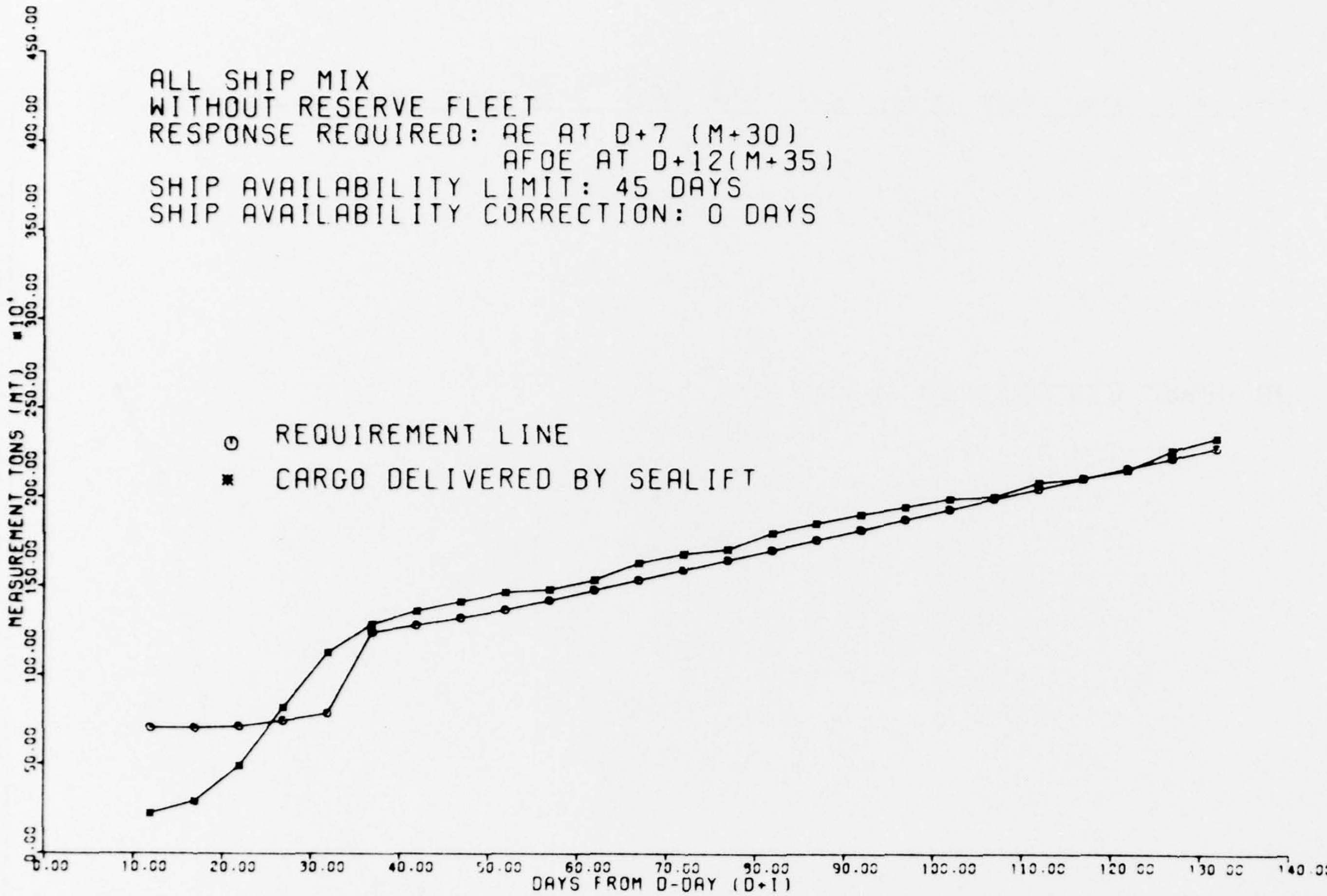

FIGURE 30 -CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE AL7

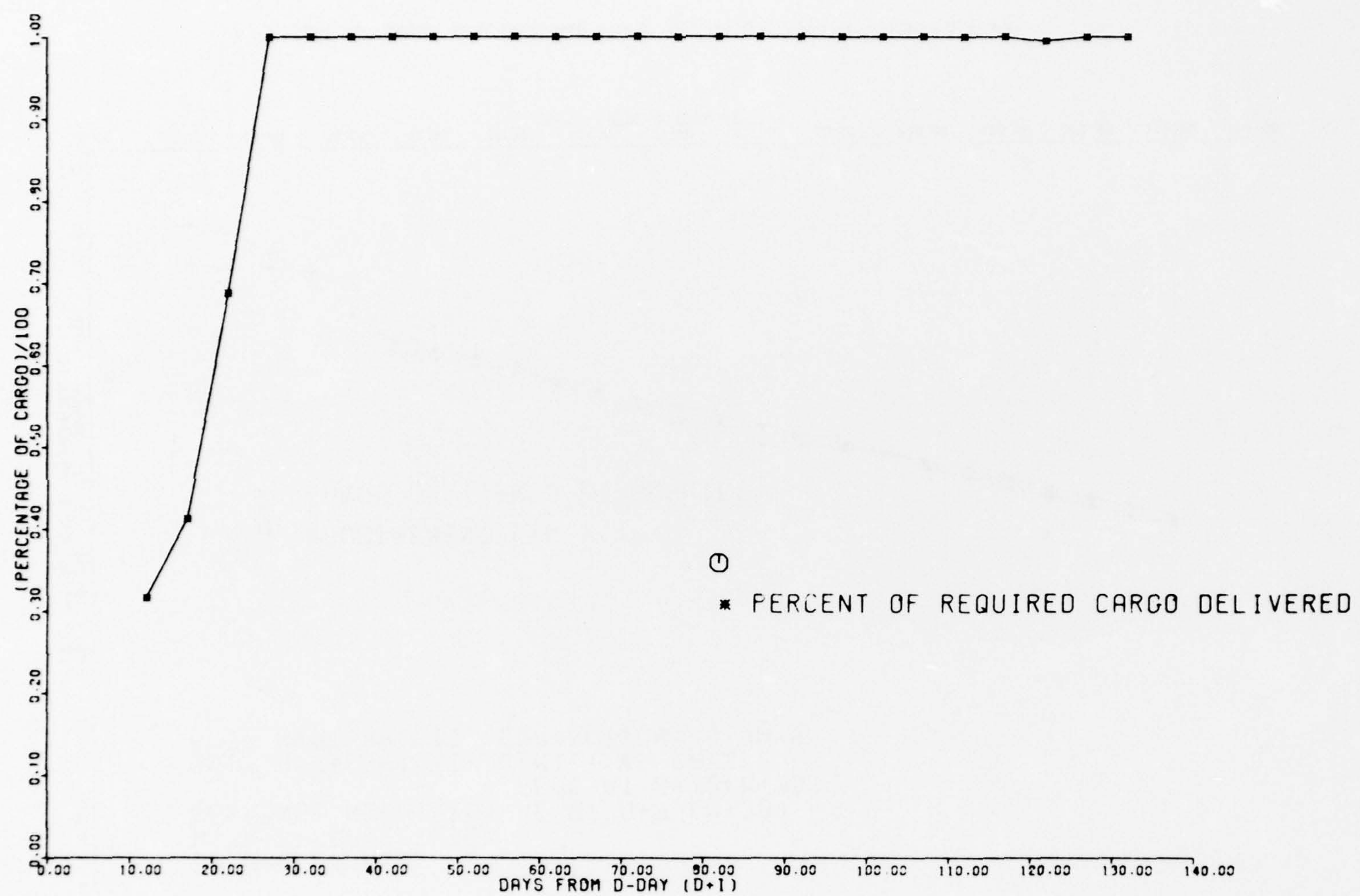

FIGURE 31 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE AL7

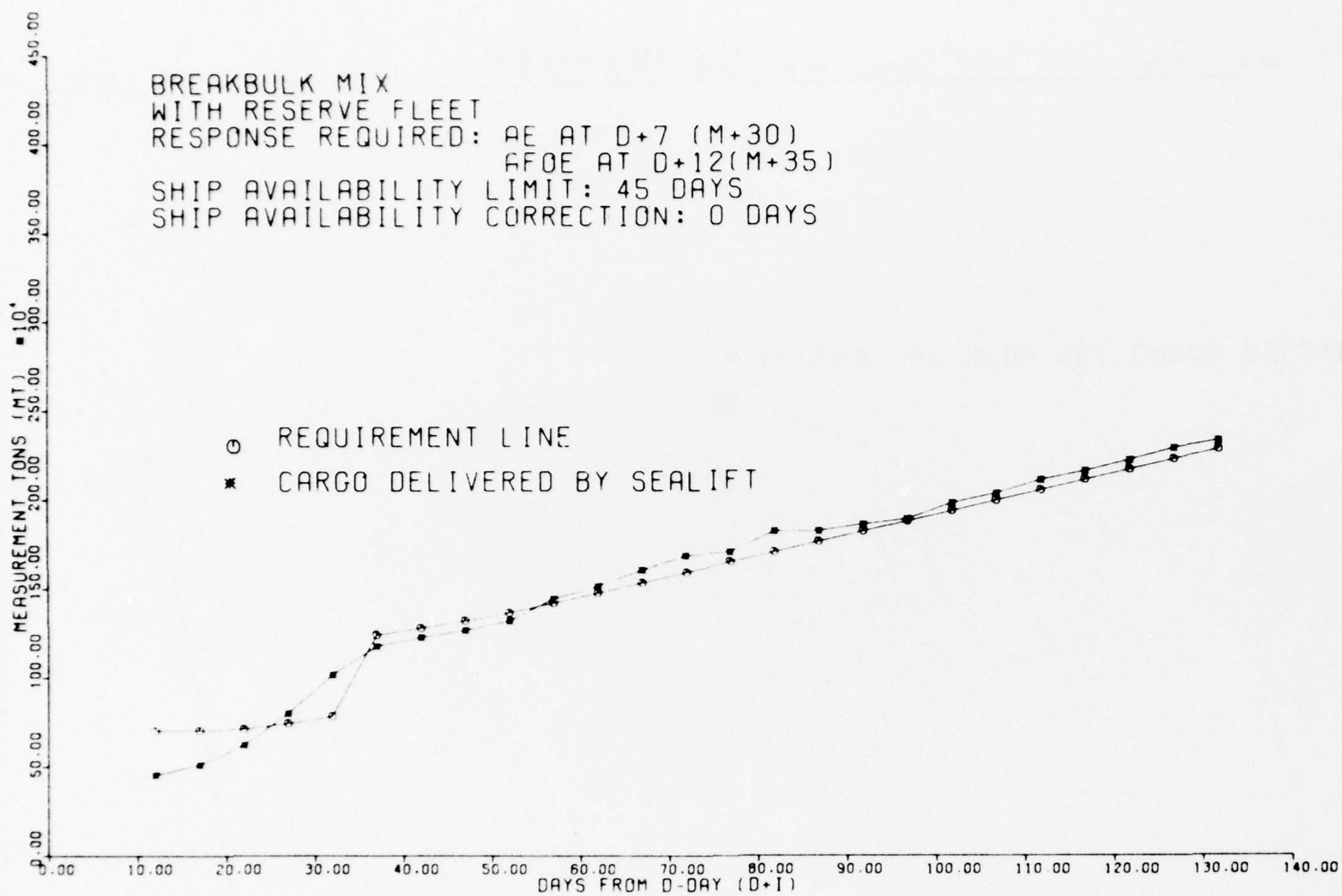

FIGURE 32 -CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE BB1

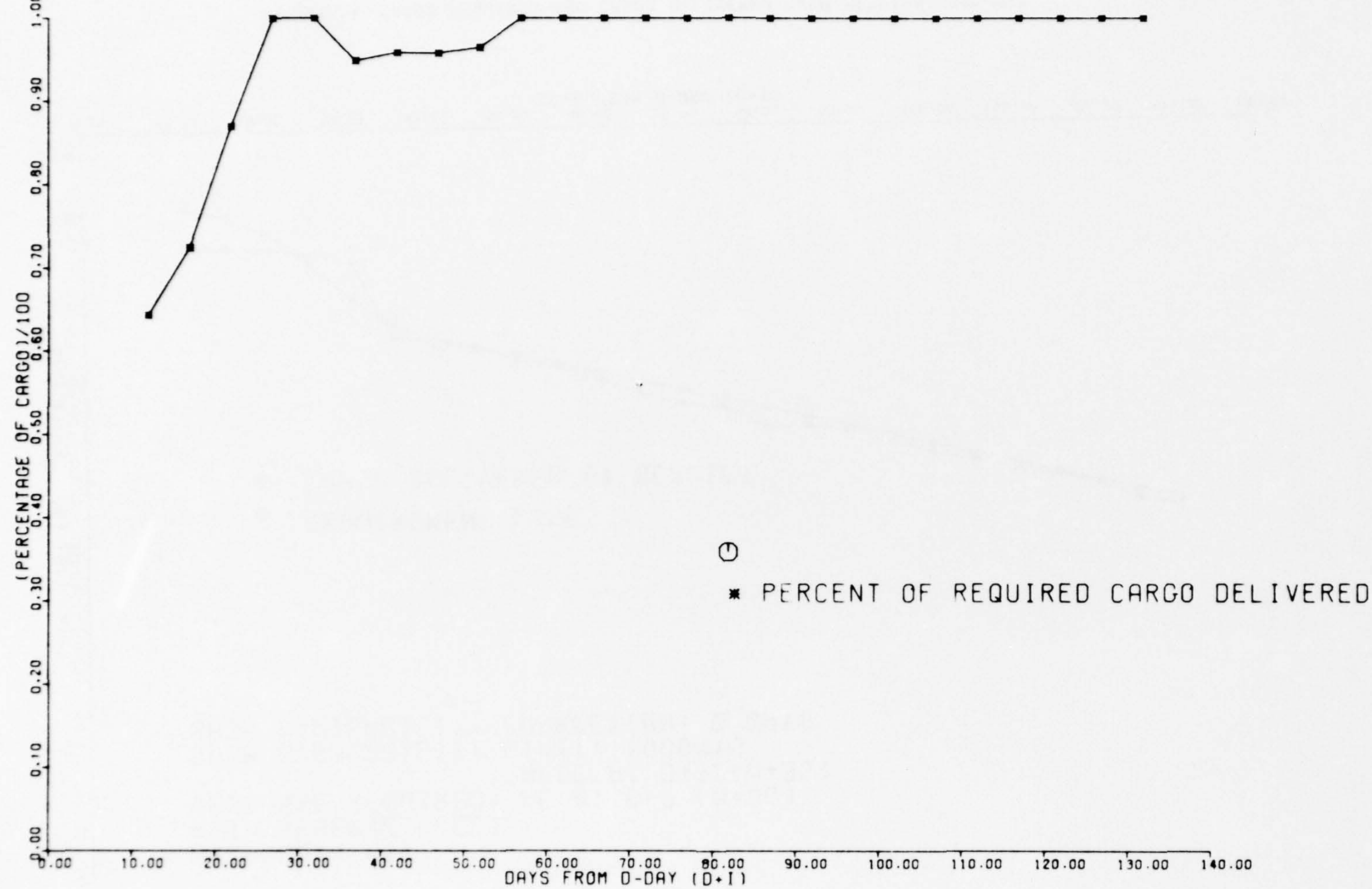

FIGURE 33 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE BB1

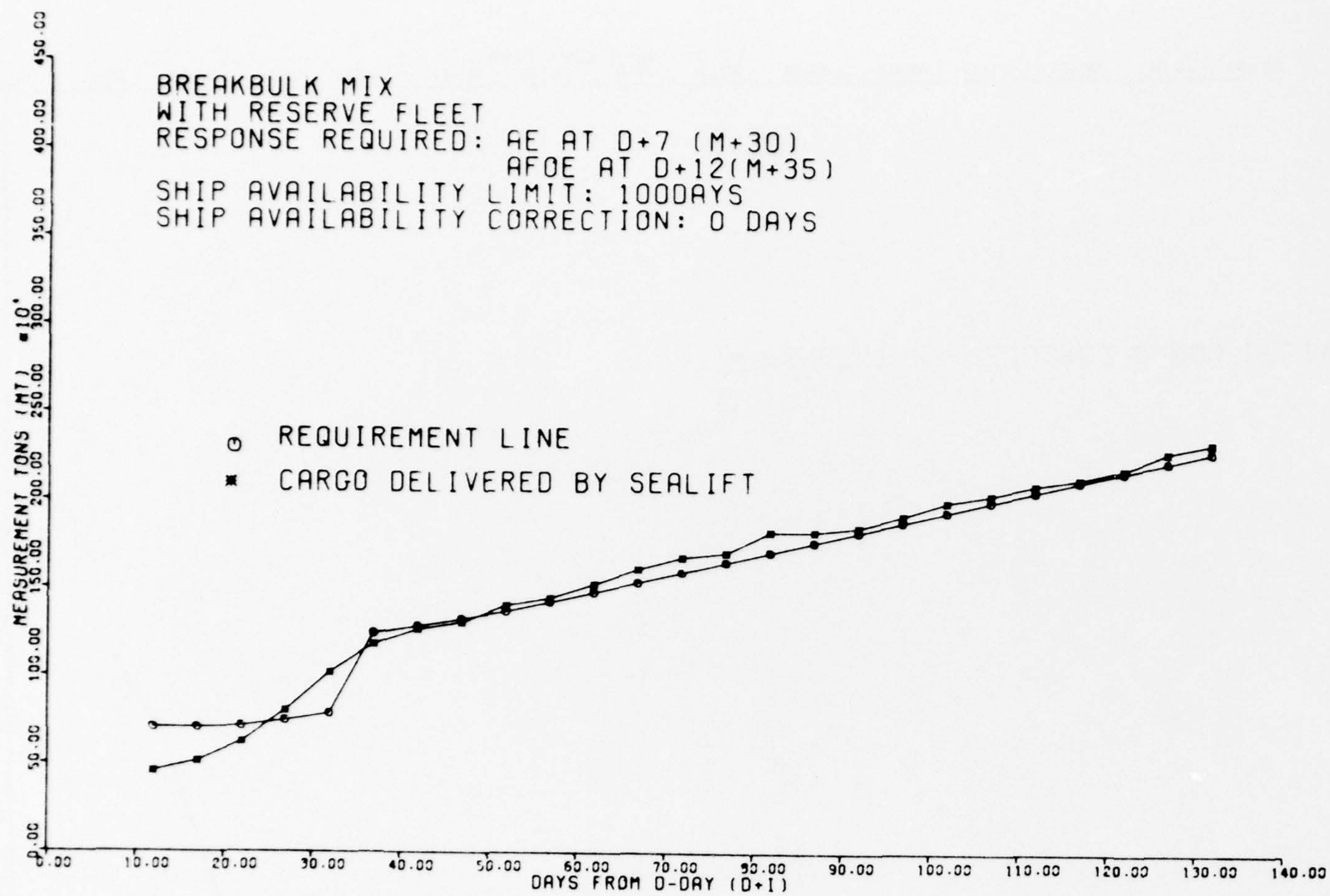

FIGURE 34 -CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE BB2

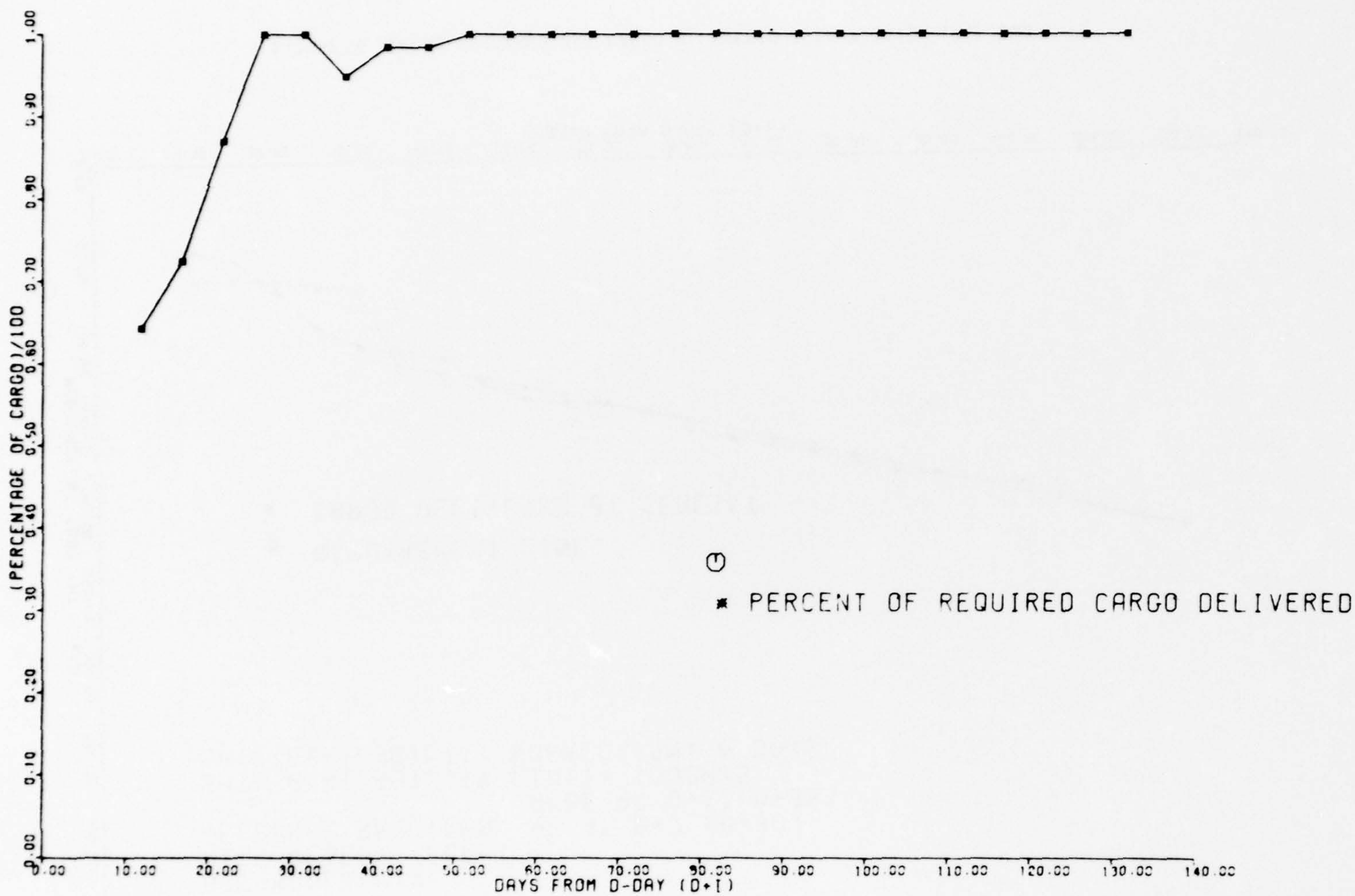

FIGURE 35 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE BB2

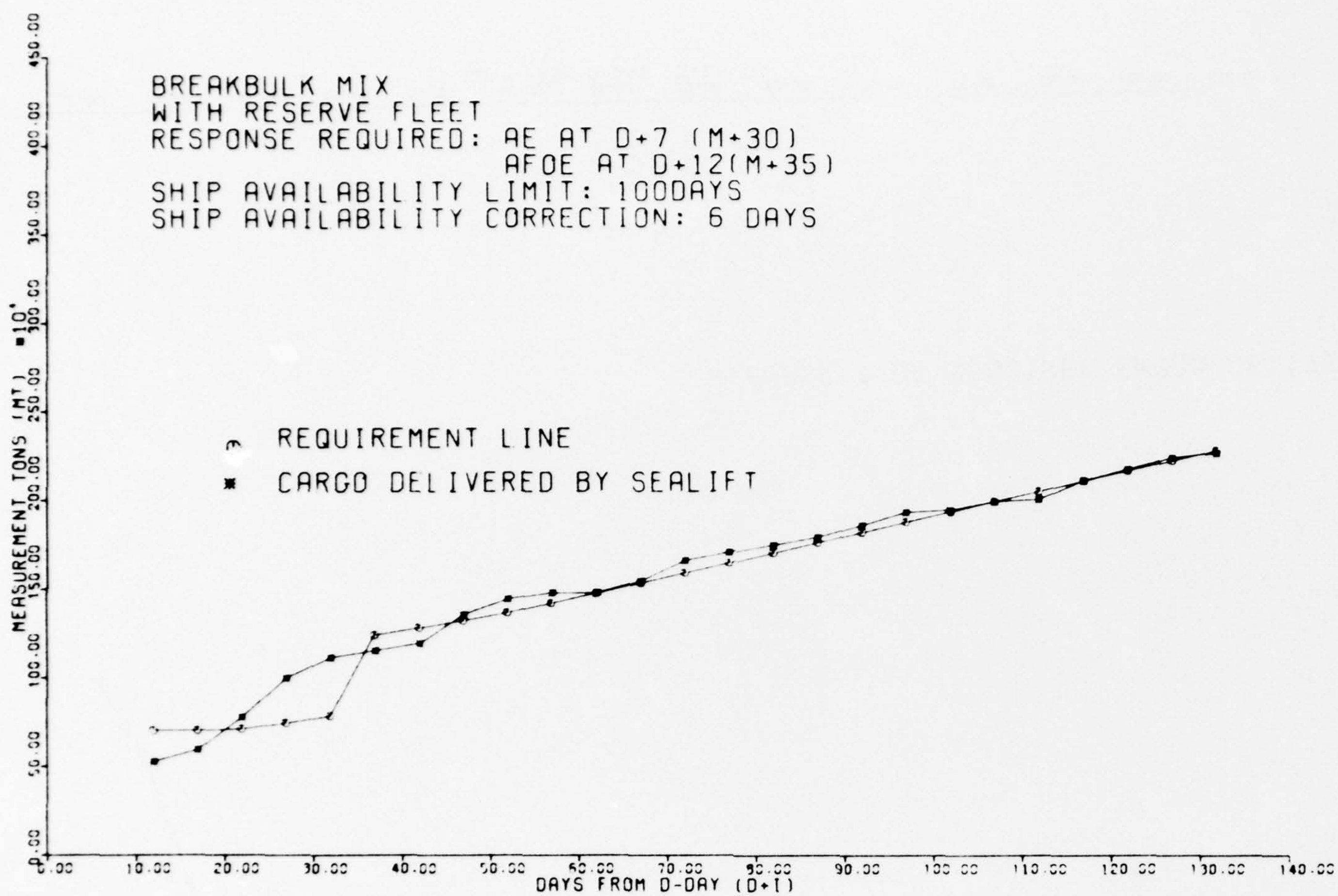

FIGURE 36 - CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE BB3

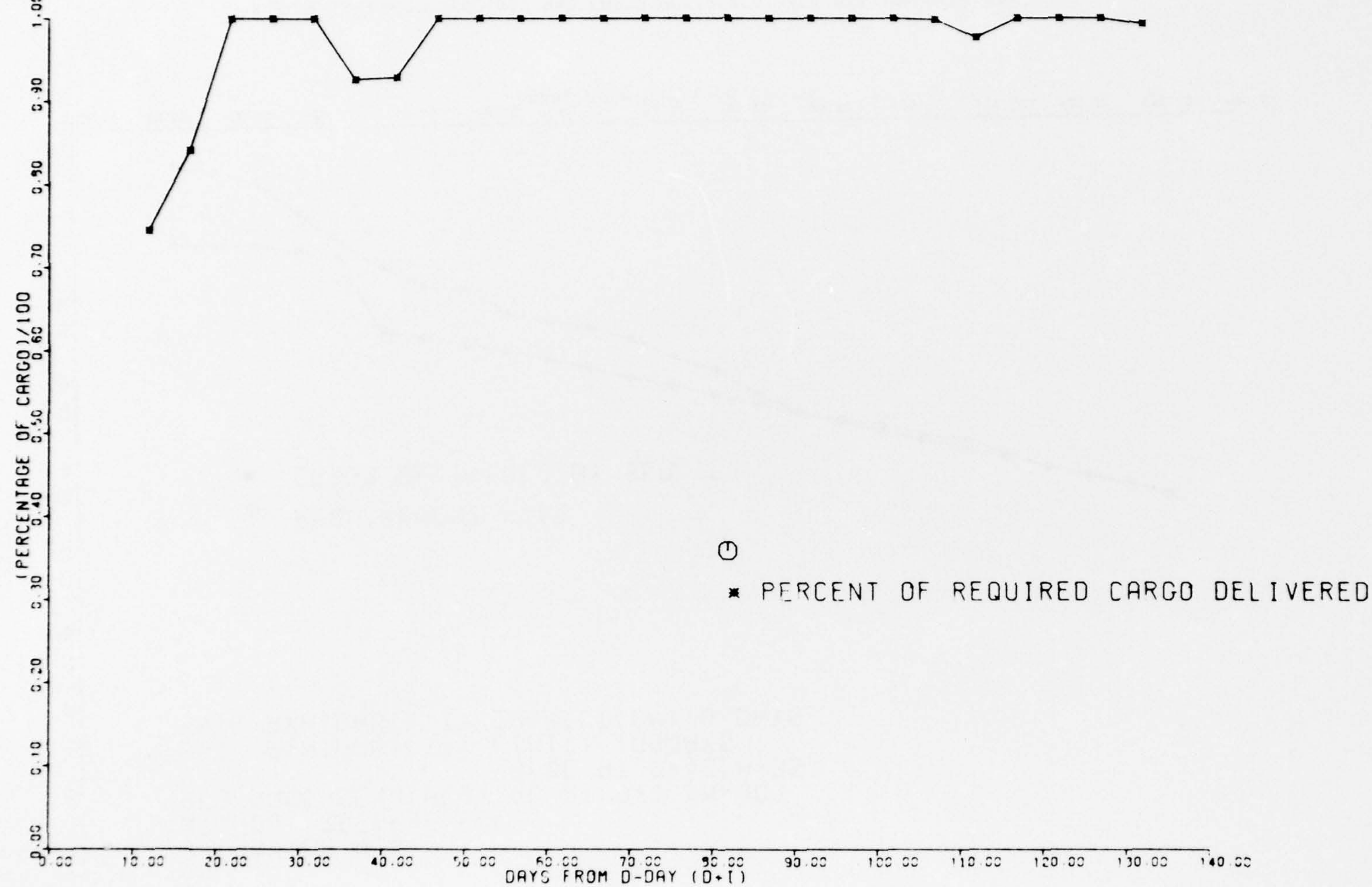

FIGURE 37 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE BB3

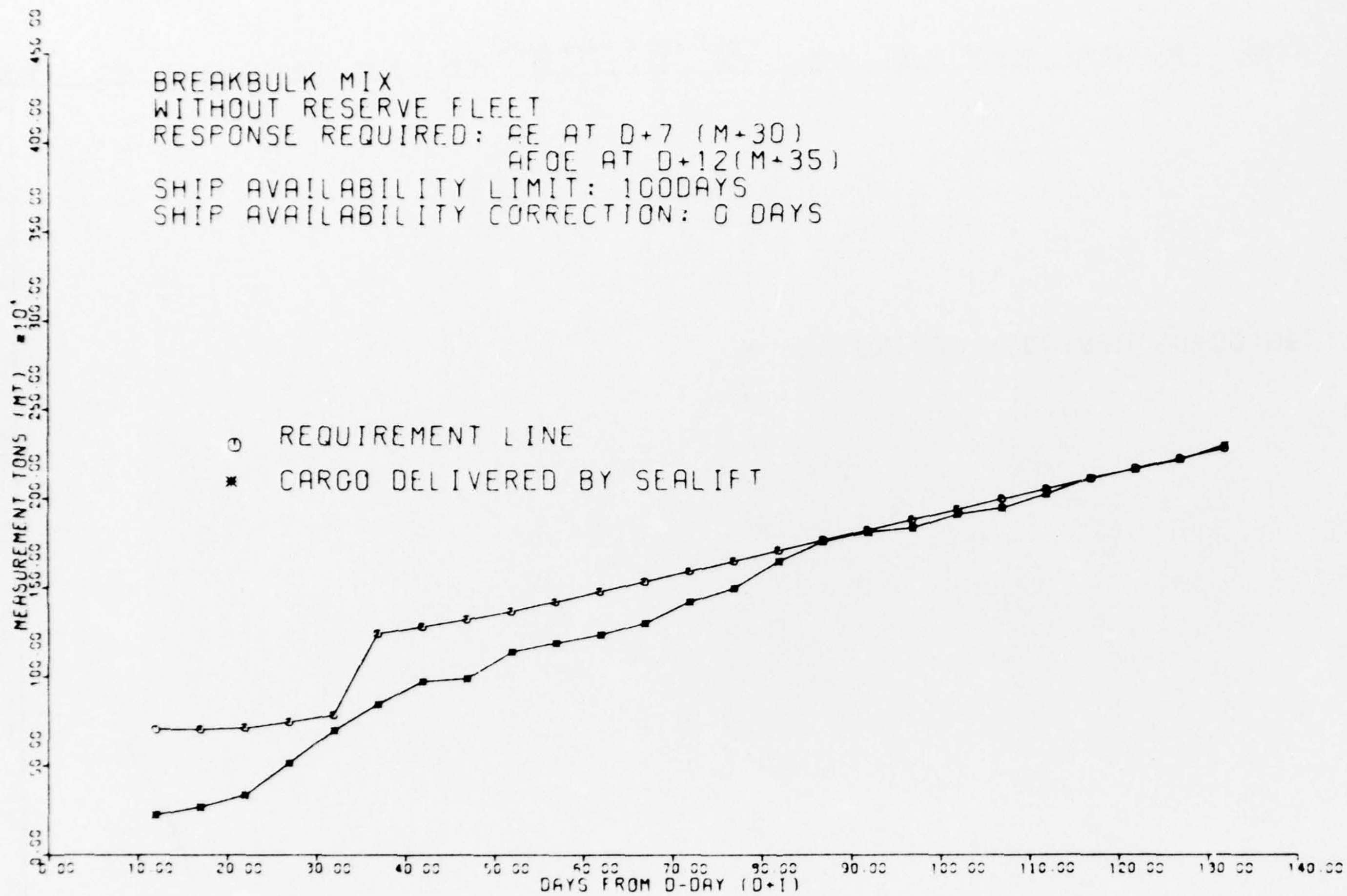

FIGURE 38-CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE BB4

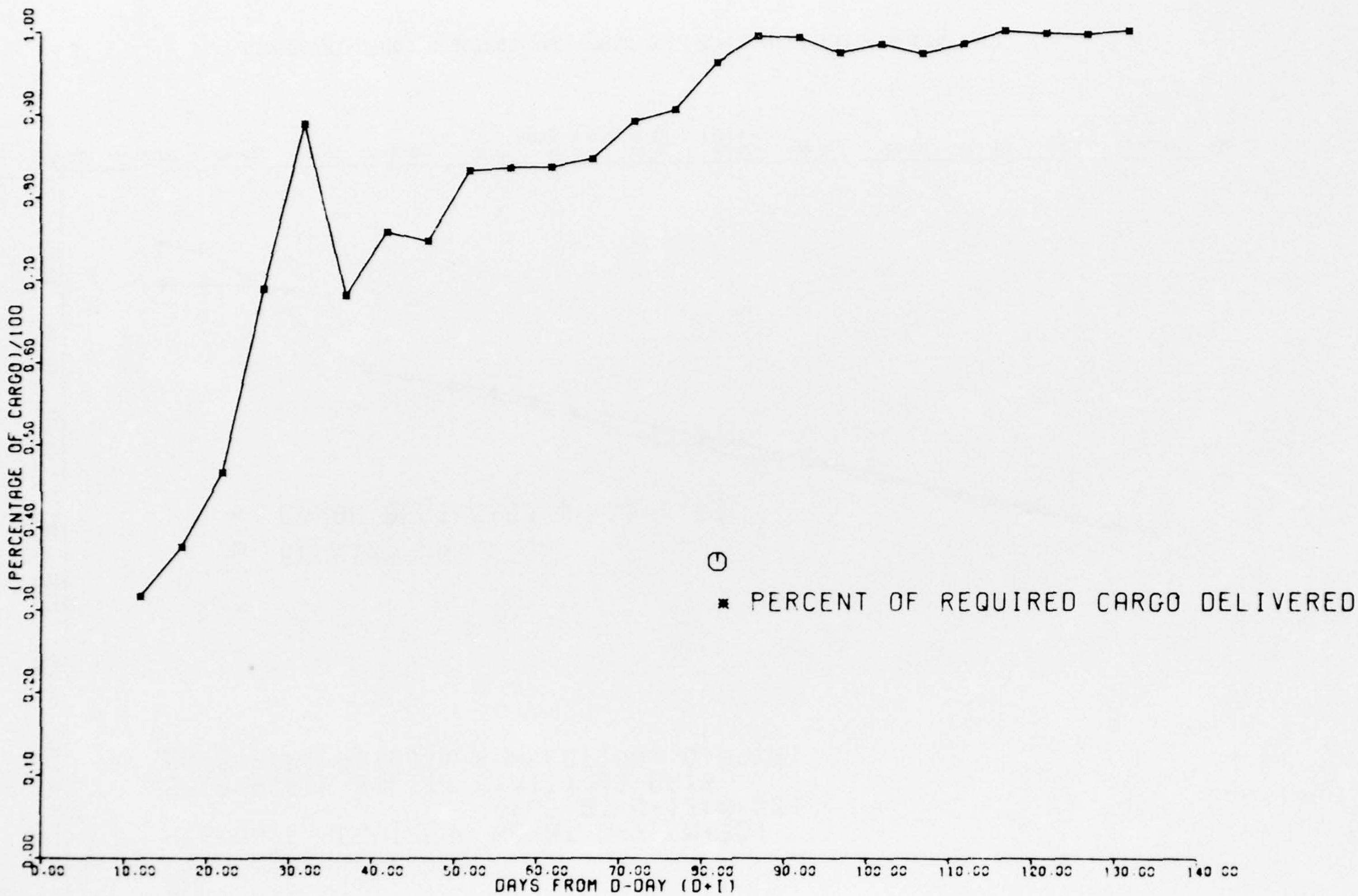

FIGURE 39 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE BB4

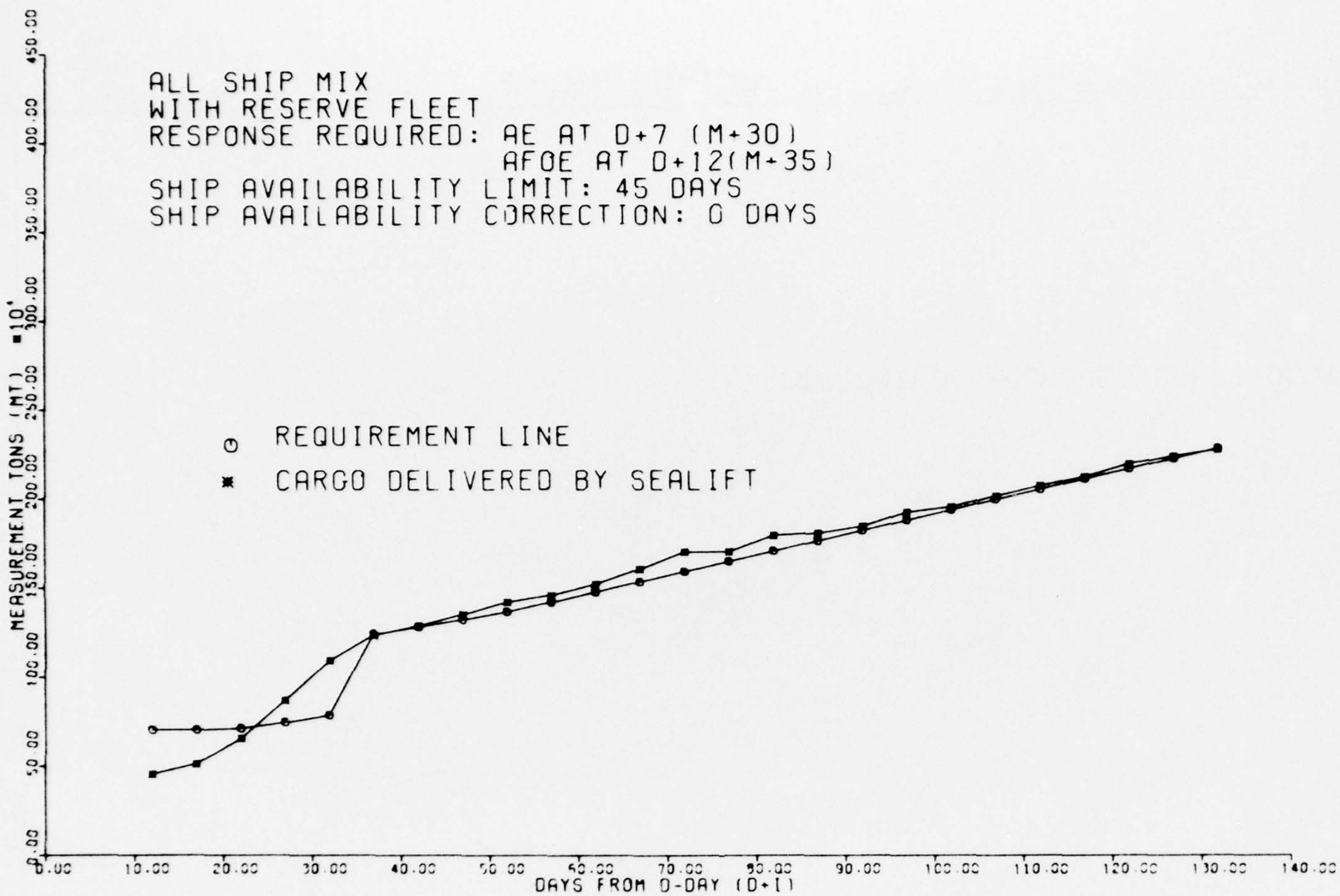

FIGURE 40 -CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE NC1

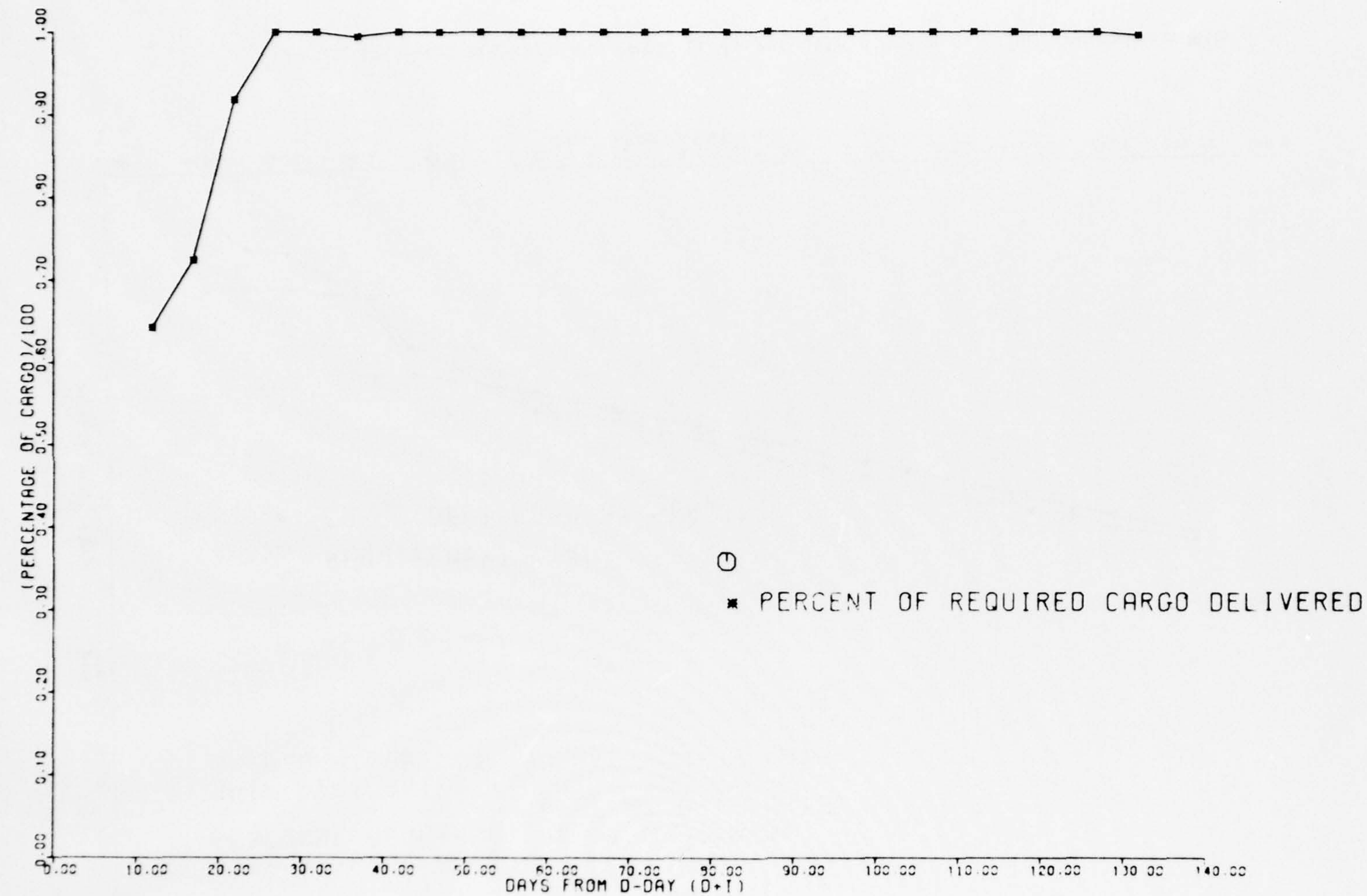

FIGURE 41 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE NC1

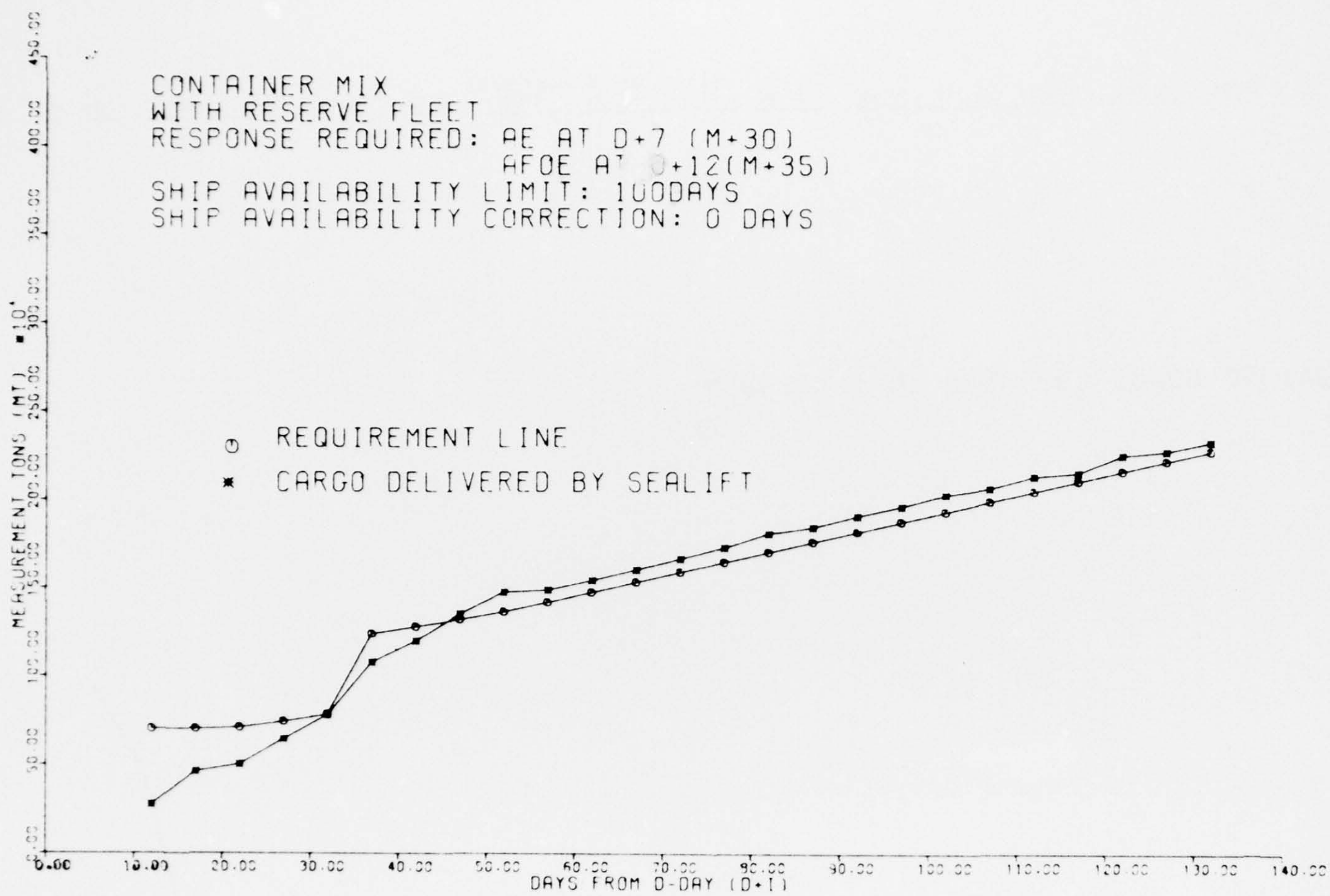

FIGURE 42 -CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE 0B1 Container Mix

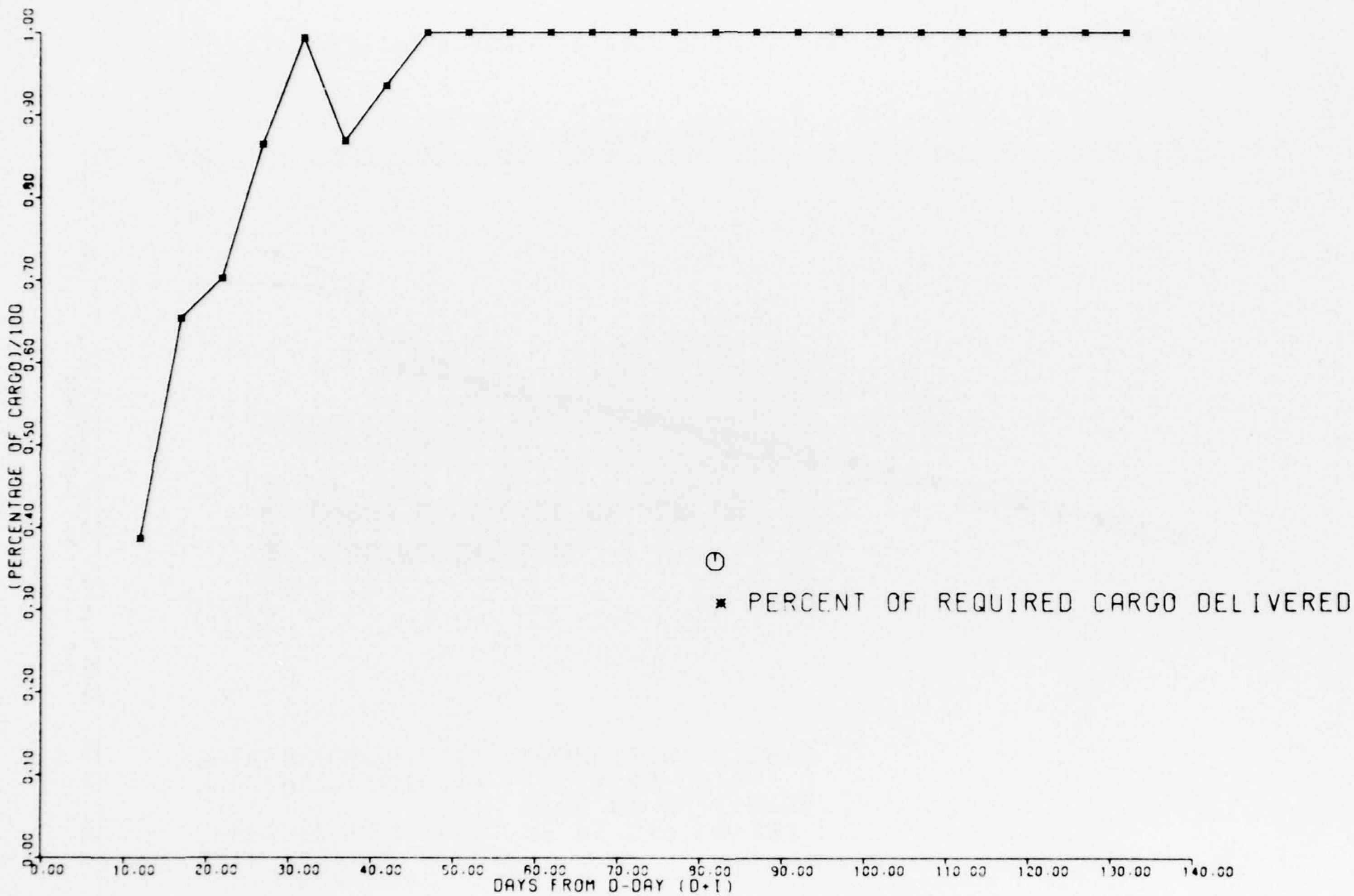

FIGURE 43 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE OB1 Container Mix

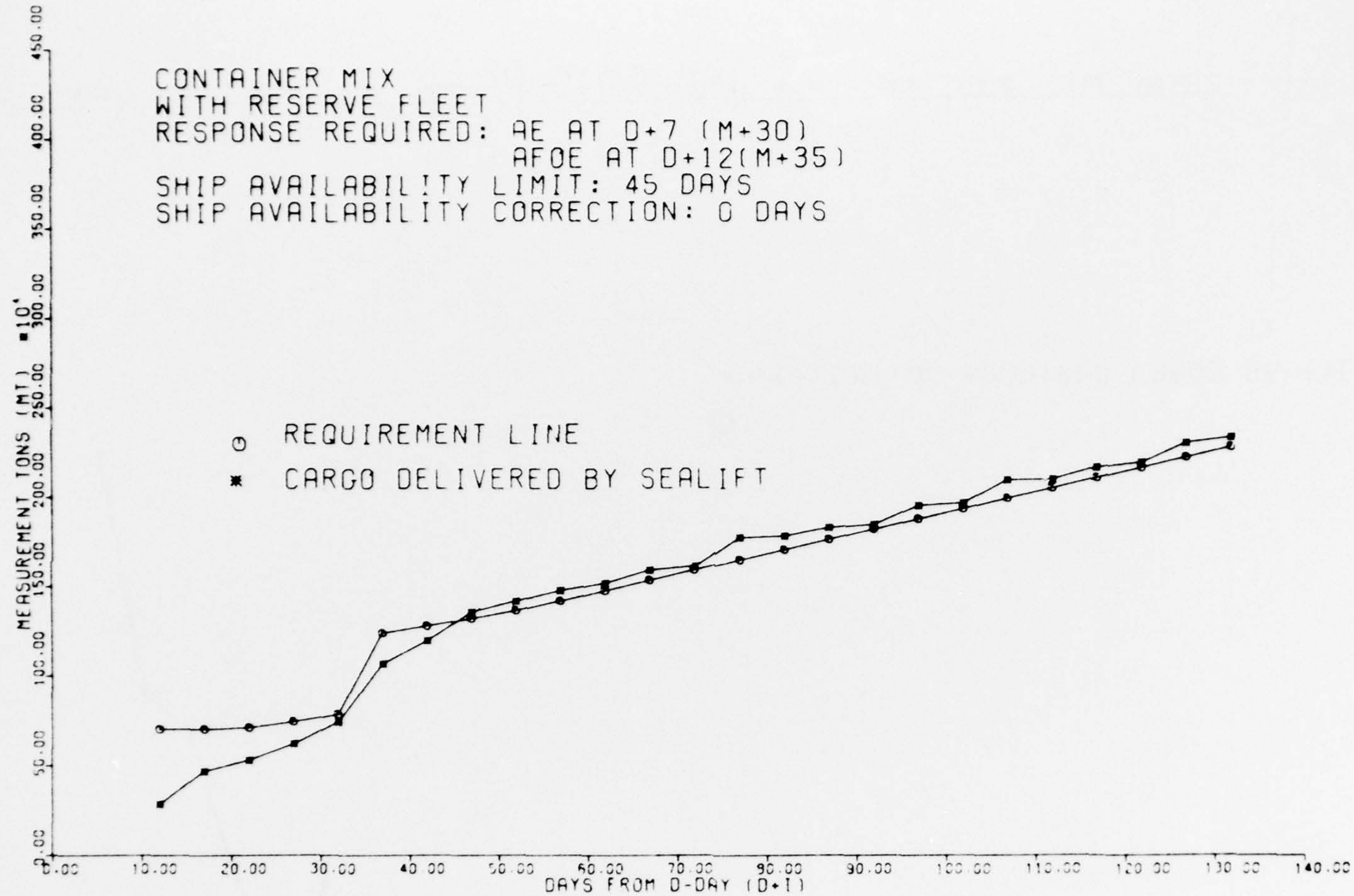

FIGURE 44 -CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE 0B2 No-Container Mix

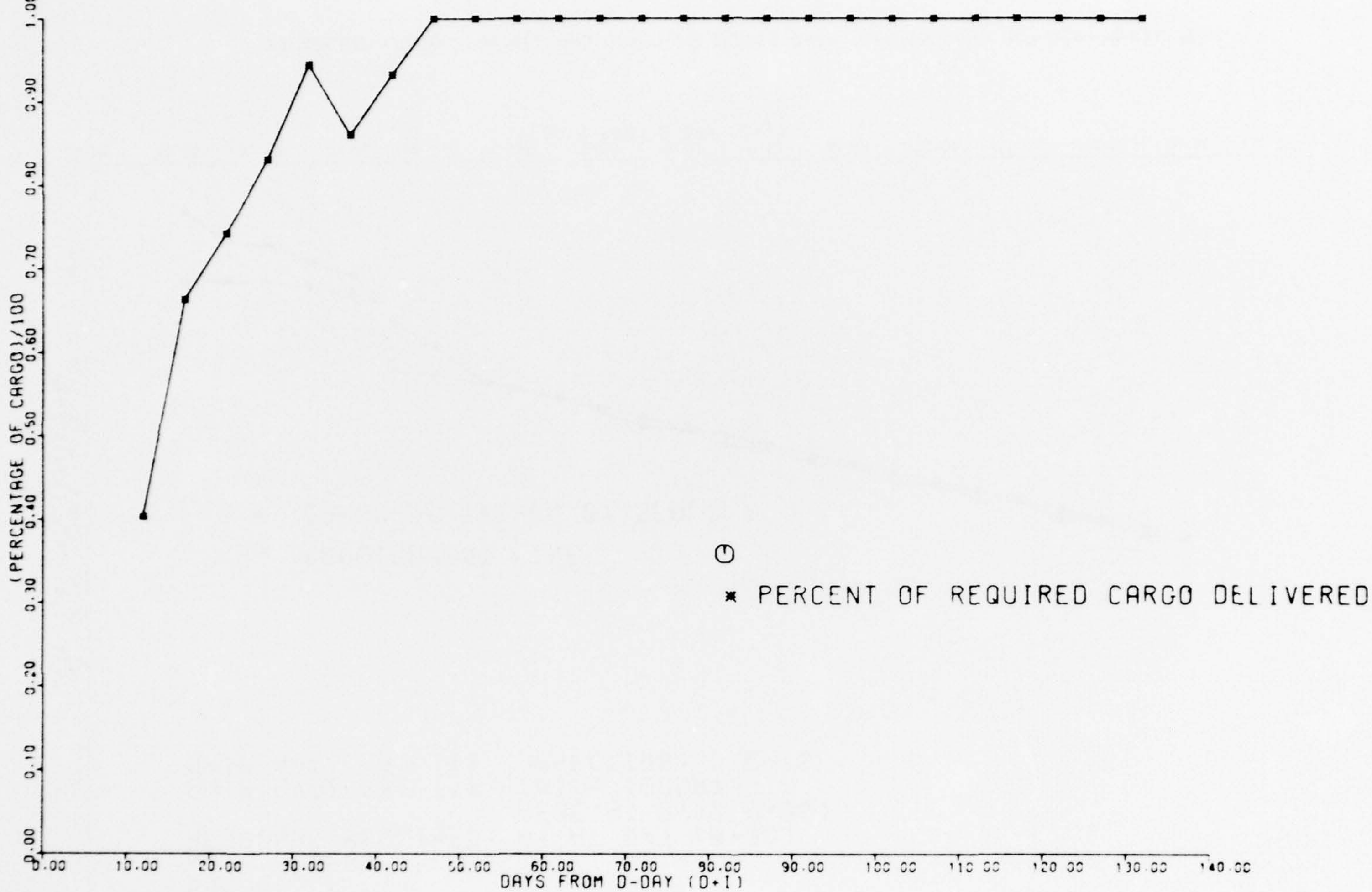

FIGURE 45 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE OB2 No-Container Mix

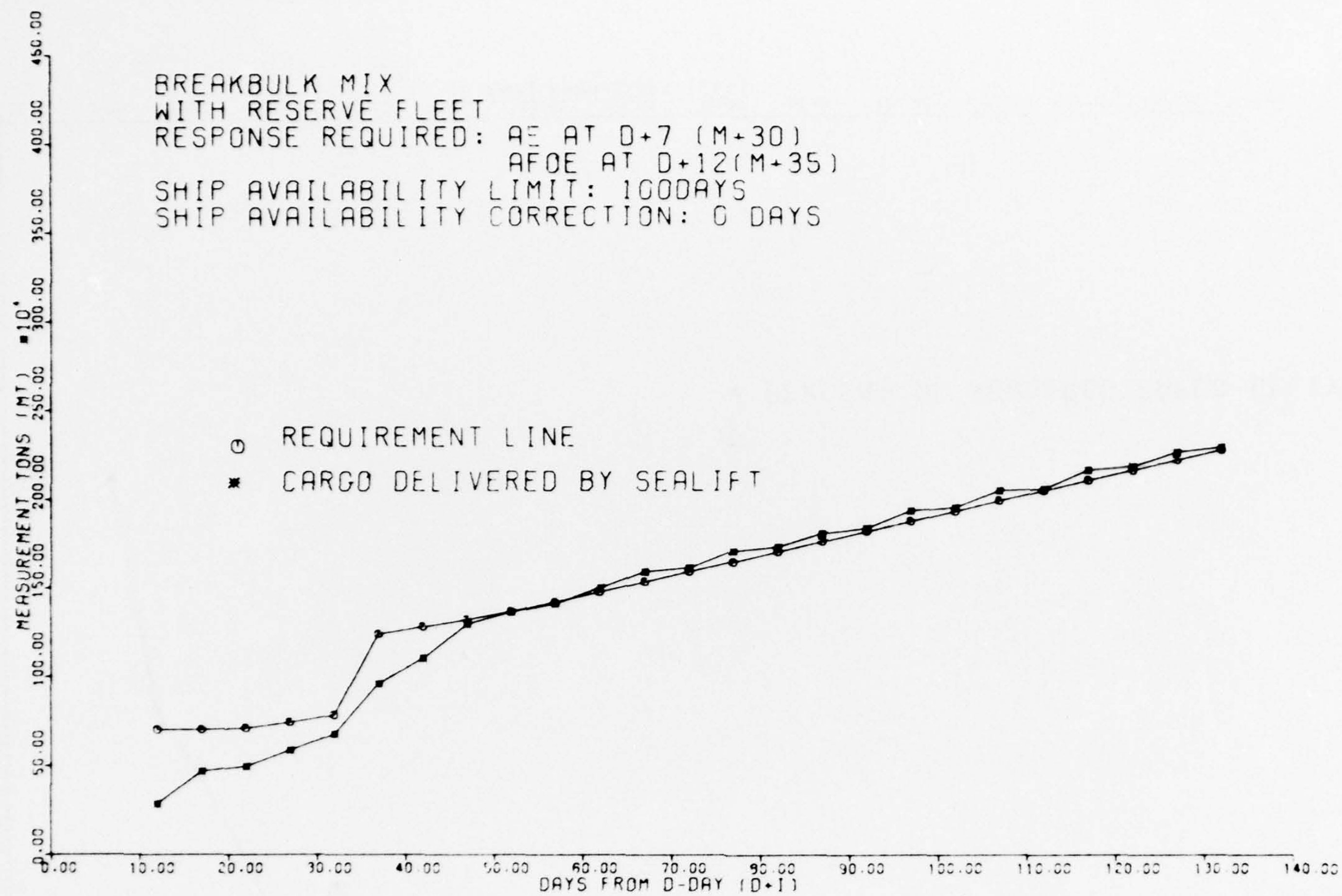

FIGURE 46 -CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE 0B3 Breakbulk Mix

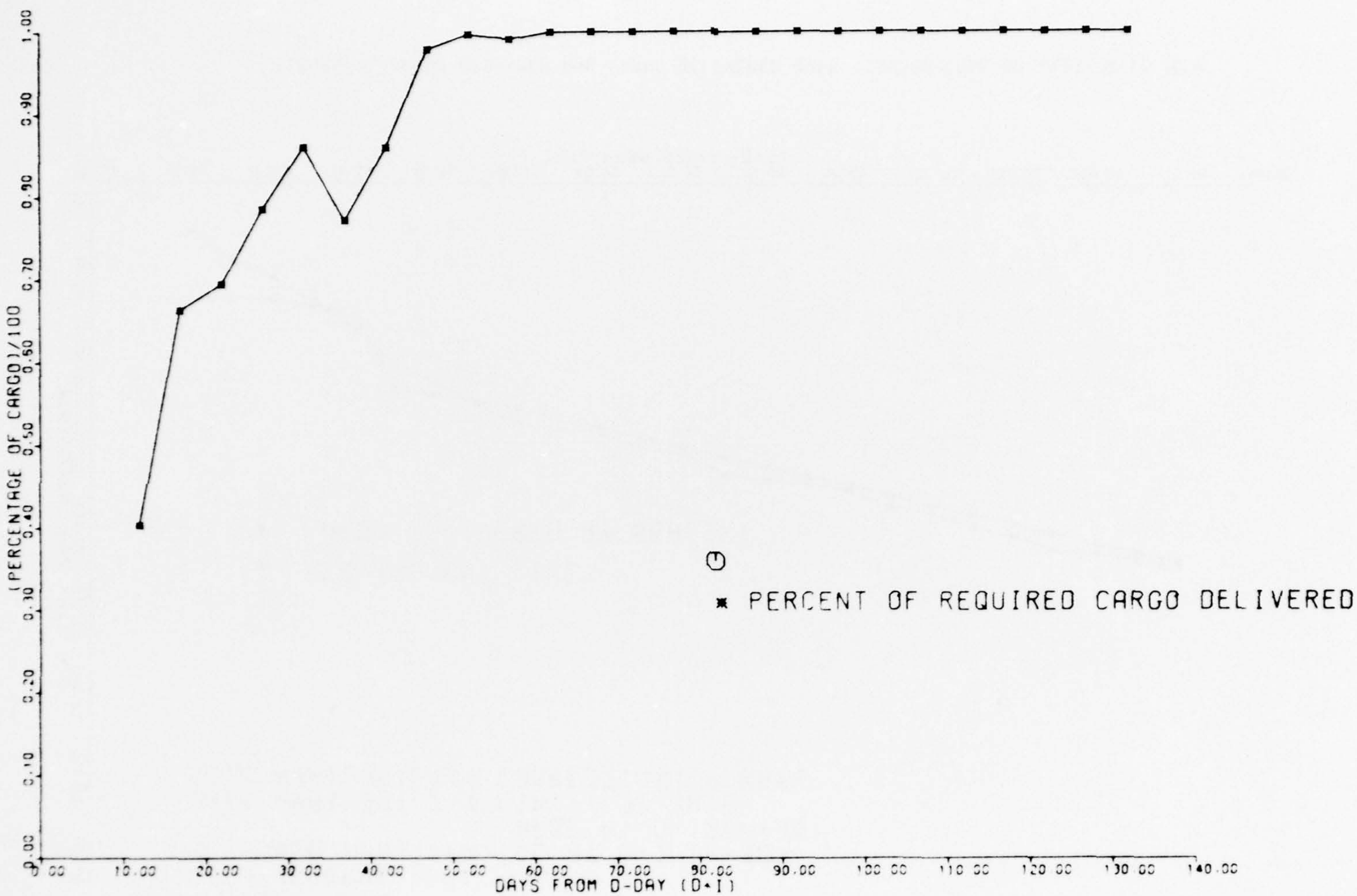

FIGURE 47 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE OB3 Breakbulk Mix

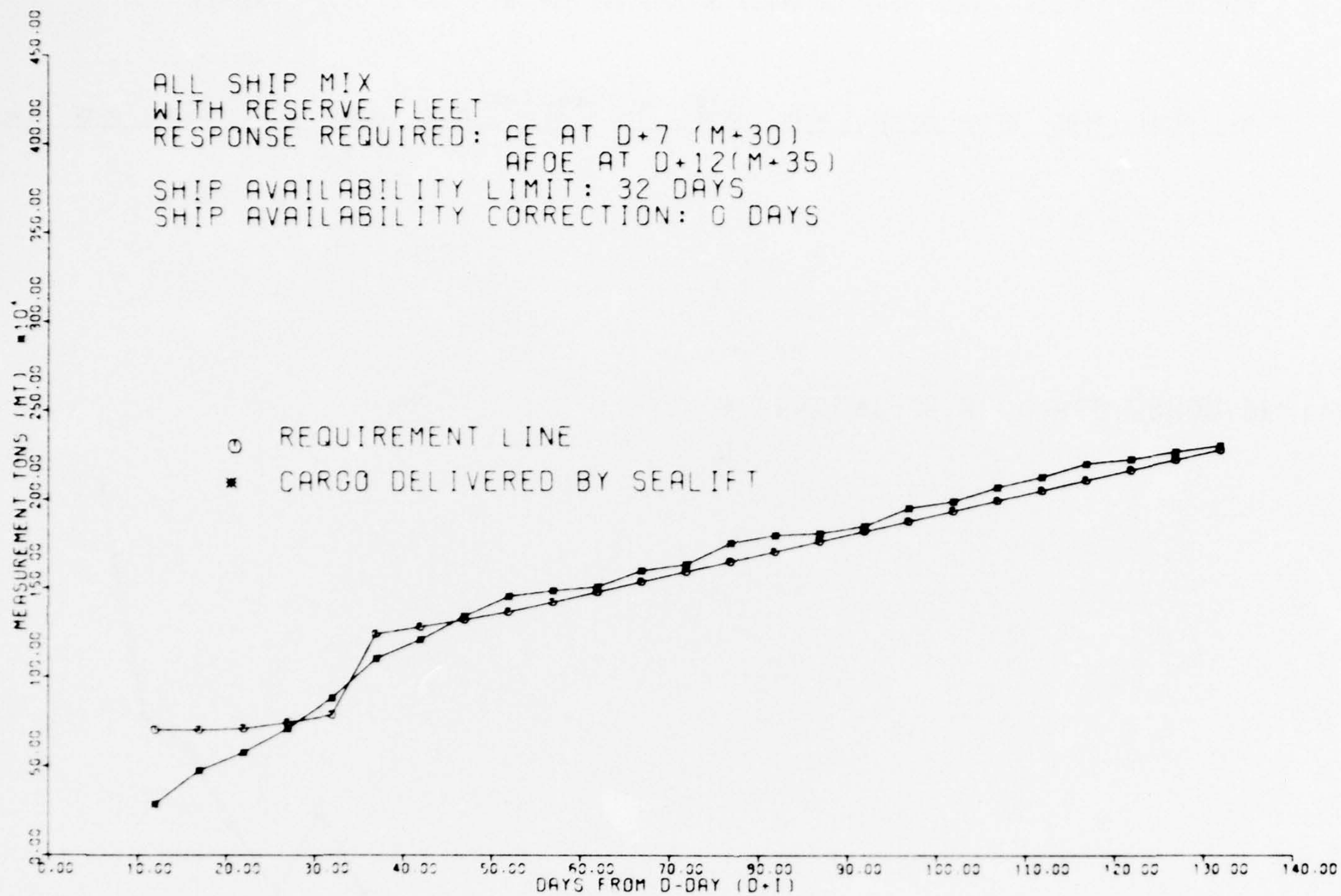

FIGURE 48 -CARGO REQUIRED AND CARGO DELIVERED OVER MISSION-CASE OB4 All-Ship Mix

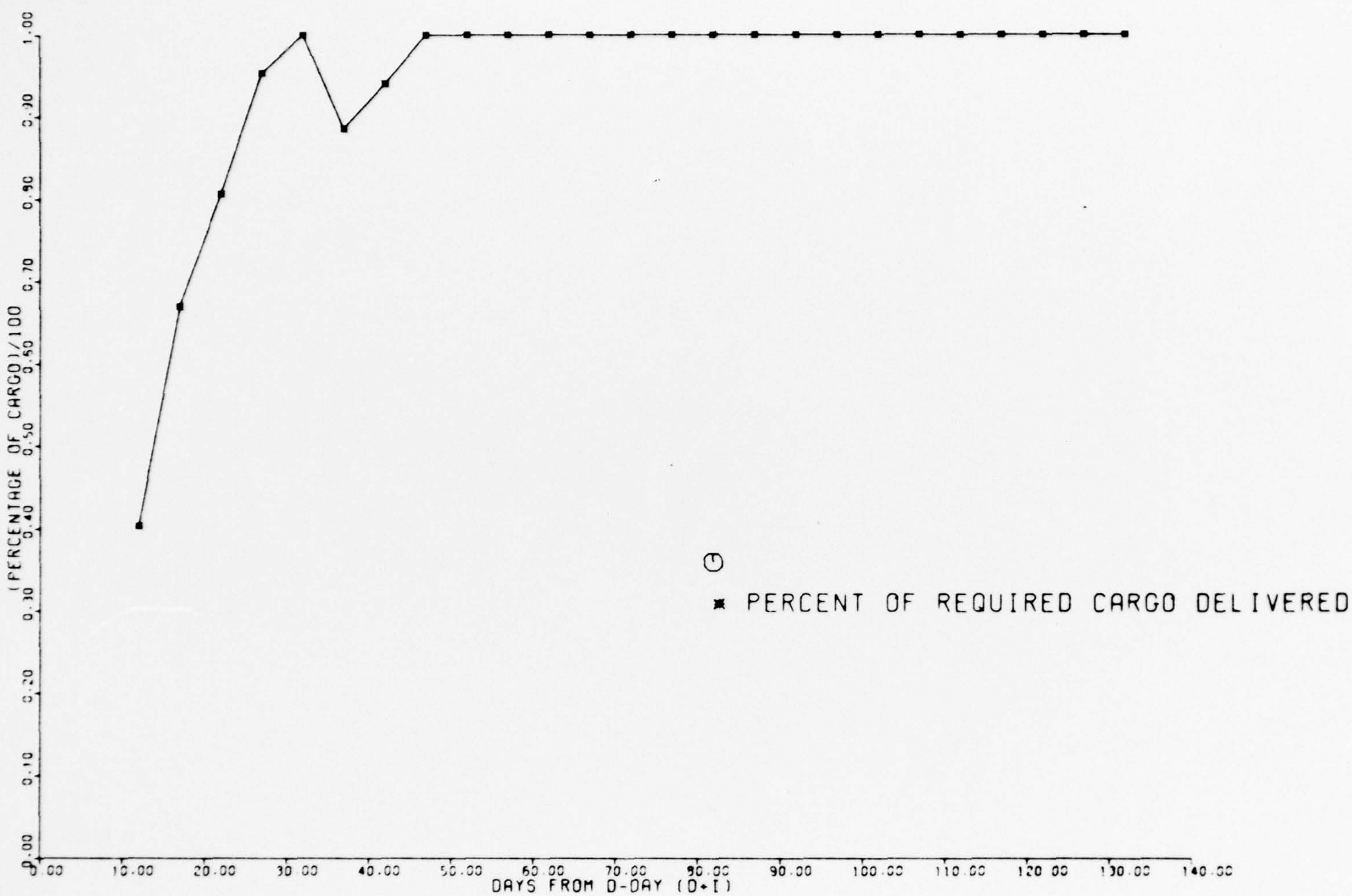

FIGURE 49 -PERCENT CARGO SHIPPED AND PERCENT CARGO DELIVERED-CASE 084 All-Ship Mix

APPENDIX C
List of Abbreviations and Acronyms

ACV	Air Cushion Vehicle
Admin MAF	Administrative MAF
AE	Assault Echelon
AFOE	Assault Follow-on Echelon
AOA	Amphibious Objective Area
CF	Causeway Ferry
CONUS	Continental United States
DOS	Days of Supply
FT	Force Troops
MAB	Marine Amphibious Brigade
MAF	Marine Amphibious Force
MAW	Marine Air Wing
MSC	Military Sealift Command
MT	Measurement Ton (40 ft^3)
REACT	Requirement Evaluated Against Cargo Transportation Computer Model
RoRo	Roll-On/Roll-Off Ship
RRF	Ready Reserve Fleet
ST	Short Ton (2000 lbs)
SRP	Sealift Readiness Program
TRADES	Transportation And Delivery of Equipment and Supplies

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